Applied Refraction

HOMER ERASTUS SMITH, M.D.

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Applied Refraction

BY

HOMER ERASTUS SMITH, M.D.

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This little book is
affectionately dedicated to

MY WIFE

whose loyalty is unswerving and
whose abiding faith is an
inspiration to me.

PREFACE

THIS book is not written for the beginner in refraction work. It assumes on the part of the reader an acquaintance with theoretic optics or so much of this as applies to the physiology of vision. It assumes also a knowledge of the properties of lenses, the effects upon light of prisms in their positions of minimal and maximal deviation, and the corresponding effects which are produced by lenses when the immergent ray falls excentric to the optic axis. It assumes that the refractionist knows what happens when there is lack of coincidence between the angle of the incident ray and the line of regard. In other words, what is the effect, prismatic and otherwise of looking obliquely through a spheric lens? The reader should not have to be told that there are essential differences in the optical properties of lenses situate at other than the anterior focal point; that thin lenses and thick lenses ground on the same radii of curvature are not alike; that periscopic or deep meniscus grinding alters the qualities of lenses of the same focal power. In short, the reader should possess a knowledge of the potentialities of the trial case and to what uses its contents may be put. It assumes also a working knowledge of apparatus for the objective tests of the refraction, the ophthalmoscope, the retinoscope and the ophthalmometer. The refractionist should be familiar also with the tests necessary to determine the amplitude of accommodation, the relative range and what is the ratio of these to the normal average for the patient's age. Lastly, and most difficult of all, he should be able to determine the equilibrium or otherwise of the extra-ocular muscles and to analyse their functions in binocular single vision. In short, this book has little to do with the science of refraction. Its purpose is the exposition of the art and to call attention to the collaterals which are also a part of this.

One does not need to have a knowledge of the higher mathematics, for while the solution of the abstruse problems of optics depends upon this, others, whose business it is, have worked these problems out and the refractionist needs only to accept their conclusions.

The writer possesses only a speaking acquaintance with the science but, in its place, he brings to bear an enthusiasm for the art, a kindly feeling for his kind which gives him an insight into their mental makeup and inspires him with an earnest hope that he shall not fail to be of service to them. To his co-workers in this fascinating field, he offers the results of his experiences, hoping that these may be helpful and an inspiration to, at least, attempt the impossible—perfect refraction work.

Homer E. Smith

New York, January 1927

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INTRODUCTION

This treatise on the art of refraction does not consider at all matters controversial. Where essentials are in doubt or there are differences of opinion the writer gives his own acceptation. If it be wrong, at least it is his own view based on thirty years' experience and he must hold to it until he is convinced of error.

He assumes, in the first place, that errors of refraction do not admit of absolutely perfect correction—using this term in the mathematical sense—that the final prescription for lenses is the mean of several refractions in the pupillary zone and that the prescription is a matter of judgment rather than of absolute accuracy. For example, the optics of the cornea show that this medium is not a surface of revolution and that its curves do not admit of perfect sphero-cylindric neutralization, and that larger or smaller pupils influence the power of the correcting lens.

Glasses that are suitable for office work need modification if they are to be worn on the links and workers in subdued light, if hyperopes need a less plus correction, or if myopes more minus. The golfer who is astigmic will not accept the same cylinder axis as does the marksman. In short, it is the personal equation which governs the selection of lenses and the psychic element dominates the scientific. Whatever in this little book appears to be dogmatic has, at least, the merit of sincerity.

CHAPTER I

THE REFRACTION ROOM

The writer believes that refraction work is a matter of applied psychology and that a serene mental attitude on the part of the patient is the first requisite. Assuming that this is true his environment in the refraction room becomes of major importance. In the first place alert mental concentration is not compatible with physical discomfort; therefore outdoor wraps must be laid aside and the chair in which the patient is to sit during the examination must be comfortable and adjustable to differences of physical contour. A seat which compels a child to stick its legs out in the air will divert its attention from the work in hand. Like perfect fitting garments, we are unconscious of their contact; the garments fit our bodies, so should the chair. Repose of body is conducive to repose of mind and this should be the first objective.

The room must lend itself to our purpose. The walls must be devoid of pictures or any salient features to catch the eye. The surface must be in matte finish to prevent reflections and be of restful color—dark olive green by choice. In no circumstance must there be any crosslights and above all, none shining behind the patient. A reflection from the back of a correcting lens before the patient's eye will undo the most careful work. If, by any chance, extraneous rays come from behind the patient, a dark cloth must be thrown over his head to prevent light from shining on the trial frame. It is much better that there be seating accommodation for the doctor's use and the patient's only. These two alone should occupy the refraction room.

When parent and child come together, it may be impolitic to exclude the former, but better work can be done with adolescents if there be no parental solicitude to intervene with ill-timed comment. If the parent must be admitted, he or she should be seated out of the patient's sight in a place where the test letters are invisible. Warning, however, should be given against any remarks whatever.

How often does it happen, when an amblyopic eye is discovered, that the parent exclaims, "Oh, Doctor, can't my child see any better than that?" with the result that the patient is perhaps frightened but surely disturbed. Or the parent bursts in with "Why, Doctor, I can't see that line myself."

The refractionist is not interested in that; the parent's vision is of no immediate concern to him but it breaks up the continuity of thought and is disconcerting to the patient. In no instance must friends or visitors be admitted nor must any talk be indulged in other than that relative to the immediate object of the visit.

THE CHAIR

It is important that the chair in which the patient sits conforms to the person and is comfortable. Repose of mind and repose of body are conjunct attitudes. As the test object and the visual line should be in coincident planes, it is necessary for persons of different statures that the seat may be placed on a higher or lower level, in other words, be adjustable for height. More than this, the comfort of the refractionist

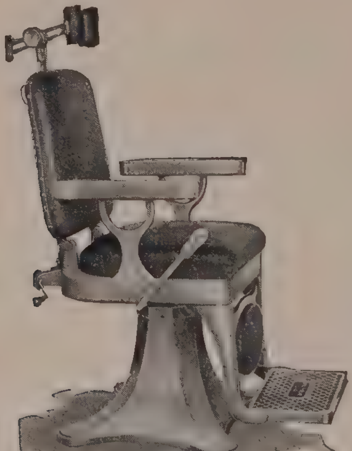


Figure 1. Refractionist's Chair

must be considered. It is tiresome and awkward either to lean over for a child, or to reach up for a very tall person. These desiderata are fulfilled in the chair here illustrated.

It is not supererogatory in this connection to speak of the refractionist himself. The same repose of mind and body so essential in the patient is doubly so in himself. Any haste, irritation or uncertainty is subtly conveyed and is disconcerting to his patient. His motions must be certain and without haste. A shaky hand will nullify intelligent purpose. If the lenses rattle against the trial frame or are not smoothly inserted into place, the patient's attention is attracted to this and away from a concentration upon the letters of the test card.

One hesitates to speak upon so obvious a detail as personal cleanliness. But don't forget that the patient's face must be touched by the fingers and that the sense of smell may be more acute than the sense of sight.

Last, but not least, the refractionist must possess tact and above all a persistency which will not admit of discouragement. The dull, the stupid and the inattentive will tax his patience to the limit but, through it all, difficulties should be only incentives to better work and their surmounting be a sufficient reward for conscientious effort.

CHAPTER II

THE TEST CHART

A poor workman will do poor work, no matter of what kind are the tools with which he works, and proportional to his incompetency the easier is he satisfied with what he has. A good workman with poor tools may turn out a fair product but the expert is handicapped, hampered and harassed unless his equipment is commensurate with his skill in its use.

It is impossible to obtain exact measurements with a yardstick where a micrometer gauge is called for or to determine the corrected or uncorrected visual acuity with a printed test chart. Usually it is hung on the wall, has black letters on a white background and is illuminated by reflected light. As a test it is worthless and its defects so glaring that nothing good can be said about it.

One might ask, why not condemn it utterly and let it go at that? Why particularize or go into detail? The answer is that if this book is to be instructive, it must deal with refined methods and that these lose their purport if applied to crude standards. The implements with which one works are secondary only to the brains behind them. To bring out clearly defects and excellencies these should be contrasted. Few realize the multitude of factors, psychic and physical, which contribute to successful and scientific refraction work and fewer still appreciate that it is the purely mechanical hindrances, inherent to the apparatus itself, which enter in to vitiate the results of the most painstaking examination.

One may know all of optics, understand fully the properties of lenses, be expert in reading into the patient's answers, the probable changes necessary in the tentative correction, and yet fail lamentably from unsuspected but wholly eliminable causes.

With this premise let the test chart be subject to critical survey. In the first place the test letters themselves. Their fractional gradations in size are in uncorrelated denominators: 200, 100, 70, 50, 40, 30, 20, 15 and 10 do not make a mutually related series and the intervals between values are too great. Assuming one hundred per cent. as standard vision (and the sides of the letters should subtend an angle of four rather than five minutes of arc) the gradations in size should be an homologous series in decimal fractions, viz: .1, .2, .3, .4, .5, .6, .7, .8, .9, 1., 1.5 and 2.0. Sometimes the letters are printed instead of being engraved and their sides do not uniformly subtend the arc they should at the testing distance. The card cannot be protected from soiling and soon the contrast between black and white becomes impaired. Not infrequently it hangs so that its surface is not at right angles to the plane of the patient's regard and thereby the letters are distorted in outline. It is a nice problem, rarely solved, so to illuminate the chart that equality of light distribution results without disturbing shadows or reflections. By no possibility can the card be so hung that every line is on a level with the patient's eyes. The top line is too high, the bottom too low and this introduces disturbing factors when the errors of refraction are being estimated. The black letters occupy relatively so small a proportion of the exposed surface that too much light is reflected into the patient's eyes. This interferes with accuracy. This defect may be minimized by making the letters white on a black background, but this minor asset is negligible, balanced against so many major liabilities.

The distance at which the card is hung seems to be governed by that inflexible rule "any old distance is good enough." However, a distance of two feet either way from twenty feet either adds or subtracts ten per cent from the recorded findings. That the whole chart must be exposed at the same time is one, if not the greatest, of its glaring defects. The patient is asked, "Read out loud the last line that is visible to you," and this is usually the answer, "But, Doctor, I can't see the last line." Here is lost time in explanations and every minute lost creates a greater chance for retinal fatigue. With a change of lenses and another request, "How well do you see now?" the response takes the form of reading the chart again, from the top down. If the refractionist permits an expression of amusement or irritation to escape him the nice rapprochement of patient and doctor is thrown out of adjustment. When the psychology of refraction work is taken up, it will be seen how serious is this episode.

A test cabinet with transilluminated letters presents fewer faults but the same objection obtains that only one of the lettered lines can be on a level with the patient's eyes, and with black letters on a white ground halation interferes with sharp definition.

In theory one line only is to be exposed at a time, in actual practice you will see several, all making for glare in the patient's eyes.

The most glaring defect of both test objects, using this adjective in a double sense, is that no provision is made for comparison under reduced illumination. Ferree and Rand have shown that in subdued light even a quarter diopter cylinder wrongly placed can cut down markedly the visual acuity which at once improves when the correct axis is ascertained.

There can be no disputing the contention that glasses fit or they do not. There is no middle ground. They are exactly right or wholly wrong. As a matter of fact patients are worse off with lenses approximately correct than they are with no glasses at all. An unglassed patient with two diopters of astigmia suffers no eye strain. All that happens is poor vision. There is not a marked visual difference, in the instance cited, between a 1.75 and a 2.25 but in either case, a painless ametropia has been converted into a most exasperating one. Besides this, even the correct cylinder if five degrees off axis produces the same result. How can one expect to attain exactitude with variable or uncertain criteria?

It is the height of the ridiculous to work with a standard that is non-existent or at best is indefinite. A perfect test cabinet is the foundation upon which scientific subjective refraction must be built. That this is axiomatic and so absolutely certain is my excuse for going at length into the shortcomings of the obsolescent, and more into detail of the modern type.

The most important feature of this is control of illumination. Where the refractionist is satisfied to give his patient twenty twentieths vision under full illumination, the correction may be wrong by a half diopter of sphere or cylinder, and in low powers of the latter by an error of ten to fifteen degrees in the axis. In other words, the patient cannot discriminate differences within this high limit of error and in consequence a false conclusion may be reached.

As has been said, glasses are either correct or otherwise and only with the exact correction can eye strain be eliminated and comfort assured. Under usual conditions the

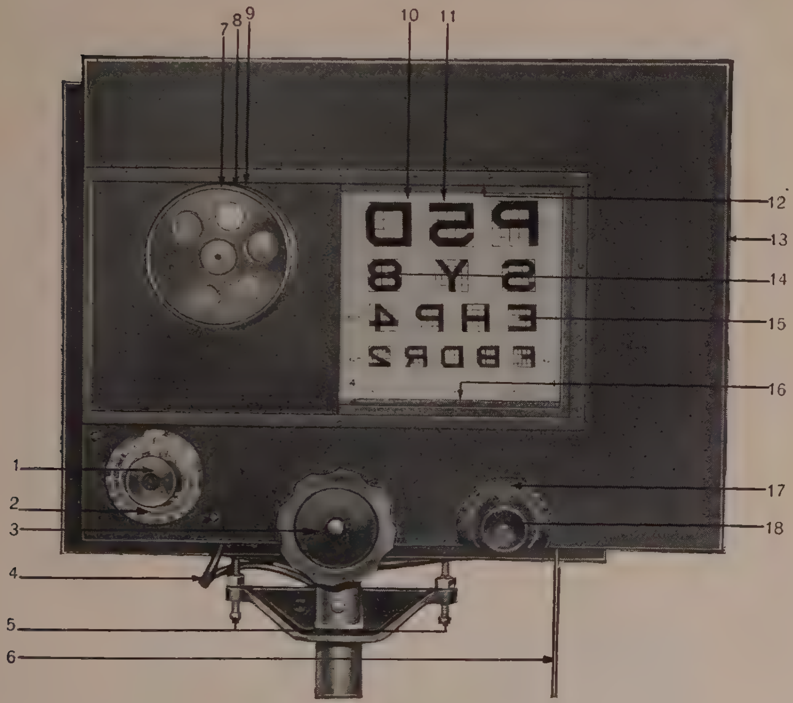


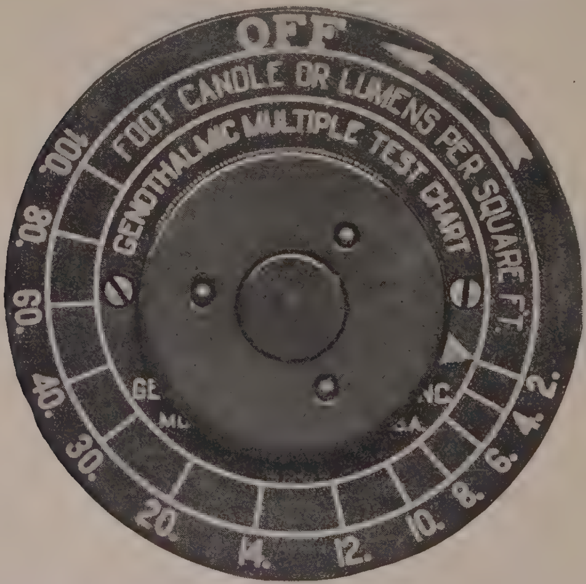
Figure 2. The Genothalmic Visual Test Apparatus

1 Illumination Control Knob.
2 Illumination Scale, Calibrated in Lumens.
3 Charts Control Wheel.
4 Electric Current Connecting Cord.
5 Chart Box Leveling Screws and Lock Nuts.
6 Pointer.
7 Disk Containing Glass to Simulate Snow, Rain, Fog and Smoke.
8 Universal Colors Disk.
9 Disk with Various Sizes of Apertures.
10 Central Fixation Chart Opening.
11 Ten Removable Charts and Astigmometer.
12 Daylight Screen (upper).
13 Access Door to Charts for Removing or Cleaning.
14 Sliding Door for Closing off Charts.
15 Interlined Characters.
16 Daylight Screen (lower).
17 Ryer Astigmometer Axis Scale.
18 Astigmometer Control Knob.

astigmatic dial is worthless. When the patient is asked which are the blacker lines, the horizontal or vertical, we get this answer, "The horizontal are blacker, Doctor, but the vertical are the clearer." This does not get you anywhere and, in my experience, the astigmatic dial is of little or no value under ordinary conditions.

With controlled illumination it has its uses. All that is necessary to insure accuracy is: Get the best vision attainable with the weakest minus or the strongest plus sphere. Reduce illumination to zero, throw in the clock dial and gradually turn on the light. The patient is asked to tell at what point one or more lines come out distinctly. When this occurs one principal meridian is located and a minus cylinder is placed at right angles to bring out with distinctness lines in the opposite direction. Turn off the light once more, again increase the illumination, and if the astigmia is corrected, all the lines will come out equally black at the same stage as did formerly the single line. If they do not, minor changes are indicated in either sphere or cylinder or both, but you have established a close approximation with speed and few motions.

When it comes down to the final nice discrimination


OFF
FOOT CANDLE OR LUMENS PER SQUARE FT.
GENOTHALMIC MULTIPLE TEST CHART
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30.
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12.
10.
8.
6.
4.
2.

Figure 3. Variable Illumination Device Controlling Knob

between values, reduced illumination makes this easy. After maximal vision has been attained under normal conditions, the light is so reduced that the test letters are just visible. At this point minor changes in axis of cylinder either way from exactitude is as discernible as would be much greater variations from this under full illumination.

In the ordinary tests, visual acuity is the only objective. The light sense has received no consideration whatever. That this is of importance is evident but there are no provisions made for estimating this in the old form of test chart. For instance, if the average eye need eight to ten foot candles to resolve the normal letters and some may do so at two and others require twelve or more, what inferences may be drawn from these examples? The first indicates a hyperæsthesia of the retina and makes it presumptive that tinted lenses would be acceptable. The second indicates a torpid light sense and tinted lenses are contra-indicated. Most valuable is this test in estimating color perception. There are patients who call the colors correctly and promptly under full illumination but who fail to do so when the light is materially reduced. It is evident that these persons should not be employed where color perception is an essential part of their work; for example, as locomotive engineers.

The test letters on the ordinary chart are of the open type and as such may be read by the acute observer even when out of focus. The makers of the test charts have, perhaps unconsciously, appreciated this and made such selections from the alphabet as will eliminate most of the letters which are so readable. But why introduce this disturbing factor which makes of the test simply a contest of wits between examiner and patient? If certain features are embodied in the form of the letters, they can be recognized only if clearly seen. If the letters be made in block form, on a square, whose sides subtend the usual angle and where intersecting lines, one minute of arc apart, fill in the rest of the square, if slightly out of focus the different letters appear alike, as a blurred square, and cannot be successfully named. To be of greater usefulness, numbers and the illiterate E are mingled with the usual alphabetical signs of corresponding sizes. One readily perceives how this makes for accuracy, and helps the patient make a nice discrimination between minute differences, when the final perfecting with the cross-cylinder comes into play.

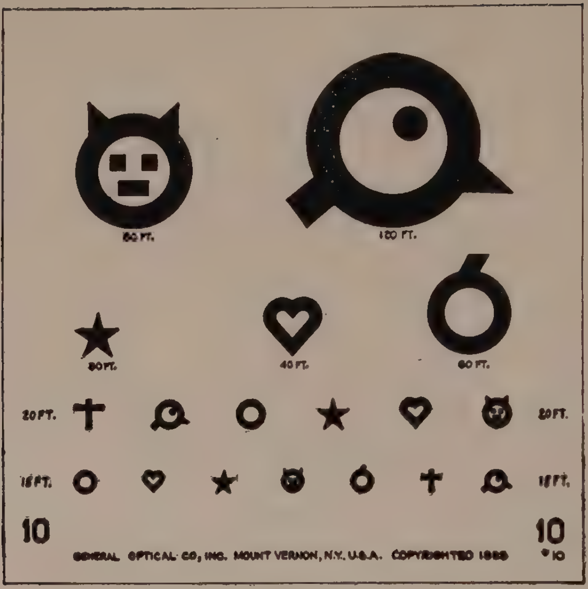
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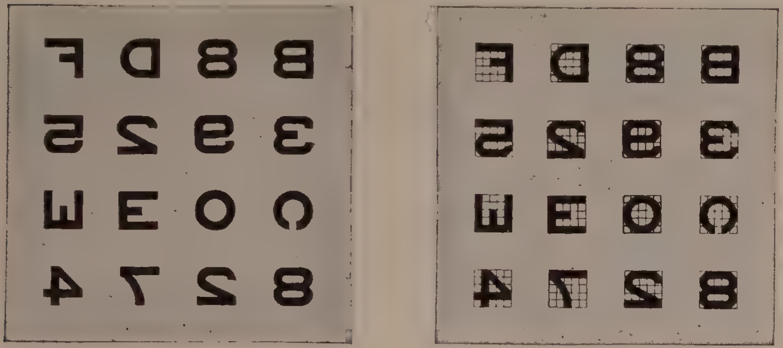
Figure 4
Chart with simple well-known characters for use with children who cannot yet read

Some of these characters should be printed in spectral red. That these reflect only the long rays of the spectrum obviates in a measure the undercorrection of hyperopes or the overcorrection of myopes and facilitates the fixation of attention.

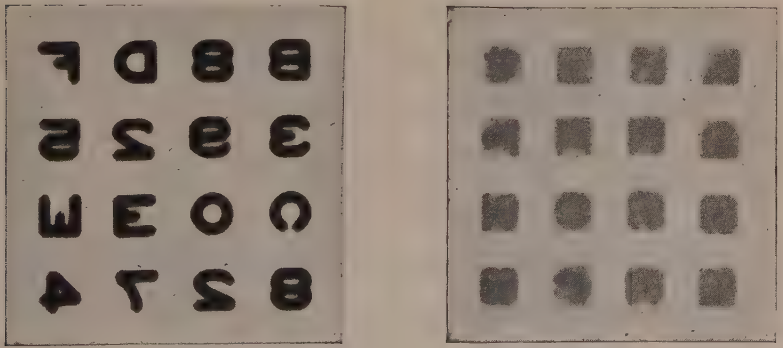
When it comes down to the final analysis, the trial case is the court of last resort, and the essence of all the tests depends upon the appreciation, by the patient, of letters clearly delineated. Any lack of clarity implies one of three things, poor vision, a poor test object or a poor refractionist.

When we approach the last fine analysis of our visual corrections, it becomes a matter of the greatest importance what shall be the criterion of the attained acuity. As I have said elsewhere 20/20 is too low a standard. We may secure this in spite of gross errors. Fewer errors will creep in if we set our mark at 20/15, but even here minor discrepancies are possible. Even a poor marksman can hit a flock of tame barns; what we should strive for is 20/10 and our target in consequence should be small and of such shape that it must be seen to be appreciated.

In the visual test apparatus the letters are in block form and interlined. Note how the interlined characters are absolutely illegible when out of focus. The test no longer rests upon a cross examination as to clarity or definition, nor does it resolve itself into a contest of wits between refractionist and patient. All that is necessary to ask is, "Can you or can



1. Open characters in focus
2. Interlined characters in focus



3. Open characters out of focus
4. Interlined characters out of focus

Figure 5

Showing appearance of the open and the interlined characters in focus and out of focus. Note the equal readability when in focus but the greater difficulty (which prevents guessing) of reading the interlined letters when not in focus.

you not read the indicated letter?" If they can, the lens is correct; if they cannot, it requires to be changed.

This, of course, is in full illumination. With this diminished to the point where some of the letters are barely discernible, it may be, and often is, found that minor changes in power or axis will work a marked improvement in clarity.

If one prefers to work with the astigmatic chart, the one here illustrated is by far the most sensitive and delicate test.

All the evil attributes of the old time test chart have been eliminated in the visual test apparatus and new features introduced which establish, for subjective refraction, criteria of scientific exactitude.

Perhaps the most valuable of these innovations is the one which provides means for testing the visual acuity under variable illumination.

Heretofore the illumination of the chart, while always

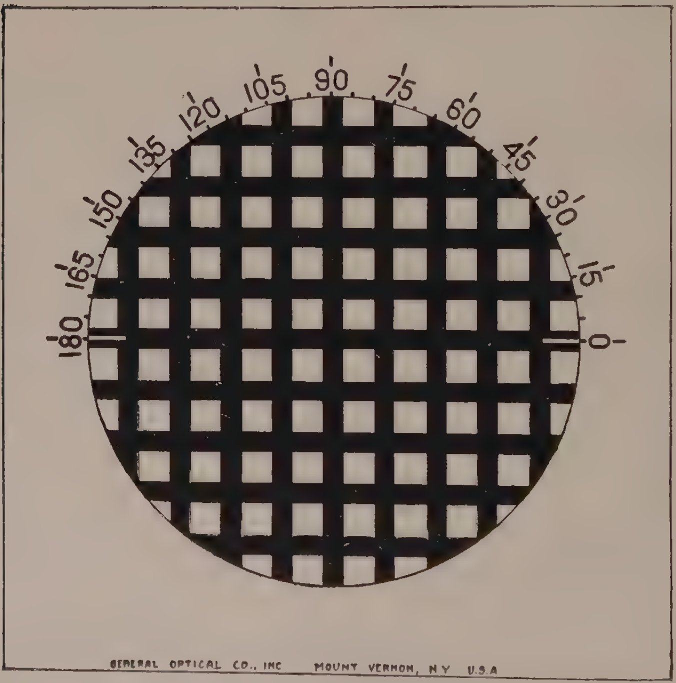


Figure 6. Astigmometer

faulty, was made more so because of a lack of facilities for varying the light intensity.

Under full illumination, fractional differences in power of sphere or cylinder or position of axes may not be discriminated, nor be appreciable as such, by the patient.

Of almost equal value is the quality of the illumination. Daylight screens give daylight values, as distinguished from the light emanating from the ordinary bulbs.

Under ordinary tests in full illumination, sensitive eyes may seem to require tinted lenses, but if resolution of detail is possible under two lumens, discomfort and visual disability will result if such lenses be given; only to those eyes which functionate best at from 8 to 10 lumens will these glasses be acceptable.

Symptoms of glare in eyes belonging to the first of these types are due to some other fault and need a more exhaustive analysis into causation. A refractionist who prescribes tinted lenses by guess is inviting trouble for himself and his patient.

CHAPTER III

THE TRIAL CASE

Only within a very short period, measurable by a few years, has the overwhelming importance of exact refraction work been recognized, and for lack of recognition no demand existed for accuracy in trial case or spectacle lenses.

The largest optical manufacturer would not guarantee that the spheric lenses corresponded to the markings upon them as to power or to the coincidence of the optical and geometrical centres. More flagrant were the errors in the cylinders. Incorrect power, inaccurate markings of the axes were common faults. More than this the spheric lenses were biconvex or biconcave, and, as used in the trial frame, did not represent the effective power of the lenses which were to be used in the glasses to be worn by the patient. The same was true of the cylinders and where the power of the spheric addition—if such was needed—was high, the resultant combination was all wrong.

Even now it is suggested, if the refractionist is working with a trial case made a few years ago, that he have his lenses gone over with a lensometer, the spheres tested for power and accurate centration and the cylinders for power and the correctness of the axis markings. Unless all the conditions for accuracy are fulfilled, no refraction can be said to be properly estimated.

Inaccurate prescribing follows. The verdict is reached on false evidence. "It is worse than a crime, it is a blunder" and one which may entail harmful and lasting consequences to the patient. Things are not just what they seem. The power of a lens, before the patient's eye, in testing, is not always expressed by the focus marked upon the handle. This would be exact only if placed in contact with the cornea. If we wish the effect say of a plus 5.00 at fourteen millimetres from the cornea, it will be attained by a plus 4.70; if minus it takes a 5.40.

When using sphero-cylinders in the trial frame, it makes a difference whether the cylinder goes in the front or the back cell and the interval between the two also modifies the findings. It also makes a difference as to how close can the trial frame be approximated to the patient's eye. It is lucky for the patient that by far the larger proportion of refractive errors fall inside plus or minus three diopters. (This means the sum of error in all meridia.) Within this limit errors incurred from the causes mentioned are very small but even so, it is a question if they be wholly negligible. A mistake of an inch more or less does not matter much if a mile is being measured, but it spells failure if even so little in the focal measurement of the lens is in error.

Differences as between the lenses made into spectacles and those used in testing are now compensated for by the better class of manufacturing opticians and are supplied as "effective power lenses" which make alike the trial case lenses and those to be used by the wearer of glasses.

The errors incident to the shape of the lenses, their distance apart and removal from the anterior focal point, are overcome in the modern trial case. In this the lenses are made plano-convex or concave, are of small diameter set in a disc of opaque material, are all of the same thickness, and in the trial frame, cylinder and sphere come in contact through their plane surfaces.

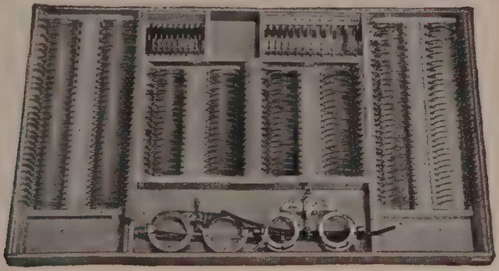


Figure 7. The Trial Case

In the trial case of an early vintage, the cylindric lenses were an abomination. These were frosted through arcs, covering up about half of the surface, the chords of which were supposed to be parallel to each other and to the axis. (Note the *supposed*.) The axes were indicated by a short line marked on the glass and so placed—with a masterly design to frustrate efficiency—that when the lens was in position in the trial frame this line, against the nickeled background of the cell, was practically invisible. As the patient's face should be in shadow, the result to the refractionist's equanimity may be imagined. More than this, unless the operator was alert, the patient would swing one edge of this frosted arc half across the pupil, cut off part of the immergent ray, decrease the area of the diffusion circle, and triumphantly read another line of the test letters, but the next instant would not see it at all. Unless this phenomenon was understood and its cause averted, it introduced a disturbing element to both patient and operator.

In the modern trial case the cylinder axes are marked by distinct lines running to the periphery of the disc and are clearly visible. The powers, both in sphere and cylinder, should be in gradations of 0.12 diopter up to 2.25, in 0.25 diopter up to 5.50, in 0.50 diopter up to ten and beyond in single units.

Part of the other equipment of the old trial case was designed simply to fill the slots and amuse the children; the varicolored tints, the plano-lens and the pair with crossed lines have no discoverable utility. The Maddox rod, the double prism, the pinhole disc and the stenopeic slit may occasionally be put to good use.

With substitutes for the trial case I have had no experience. To my mind, however, their disadvantages overshadow their good qualities. Perhaps to one expert in their use they may fill a useful purpose for quick estimation of gross errors, but for the niceties of refraction work, they are inadequate. The complicated accessories for testing imbalances of the ocular muscles fail of their purpose because only imbalances in the primary position fall within their province. As will be shown later, findings so obtained may be wholy fallacious. Heterophorias in this position give no clue to the muscle involved, nor do they indicate what should be the method of correction.

CHAPTER IV

THE TRIAL FRAME

Until something better is devised, one must work with what one has. When many diverse remedies are advocated for any disease, you may be sure that none are good. There are many models of trial frames. What is the answer? What are the requisites for the best one? First, it must be light in weight; second, the nose-piece must fit comfortably, and be adjustable for height and depth; third, the cells, three in number, should be so constructed as to permit of the lenses being placed close together. The middle cell to be bounded by the axis marker comprising an arc of one hundred and eighty degrees, the markings on which should be in durable enamel, well contrasted and easily legible. This cell should not be rotatable, and have neither ratchet nor clips. The cells should be adjustable for pupillary distance, not because this needs to be measured, but because the patient must look through the centers of the lenses when the refraction is being tested.

Adjustability for eyes on different levels is wholly unnecessary. If there is a marked discrepancy in this respect the trial frame is to be so placed that the end pieces are aligned with the outer canthi, and this introduces what is the greatest need in a workable trial frame, viz., the temples. To fulfill this need they should be straight and not riding bows, adjustable to cling closely but not uncomfortably to the sides of the head, so constructed that they may be placed parallel or at an angle to each other and finally, when their proper position has been determined, they may be locked firmly in that place.

One may be sure that when the need is urgent man's ingenuity will awaken to meet that need. Even while this chapter was being written a model was under construction to overcome all the faults of the old and to unify the requisites of the perfect trial frame.

Note what has been said of how faulty are the old instruments and what are the desiderata in the new. The new trial frame is still "on the fire." That is to say, the new model is hand-forged and dies for quantity production have yet to be made, but the design is perfected and I have tried it out personally.

It is graceful in outline, light in weight and in addition is so constructed that it compensates for the overhang of the brow and thus admits of a closer approximation of the lenses to the eye. Best of all, the temples may be angulated for an adjustment to ears on different levels and can be made to conform to heads of greater or lesser widths. There are no hooks to go behind the ears and therefore the temples are easily placed in position without disturbing the arrangement of a woman's hair.

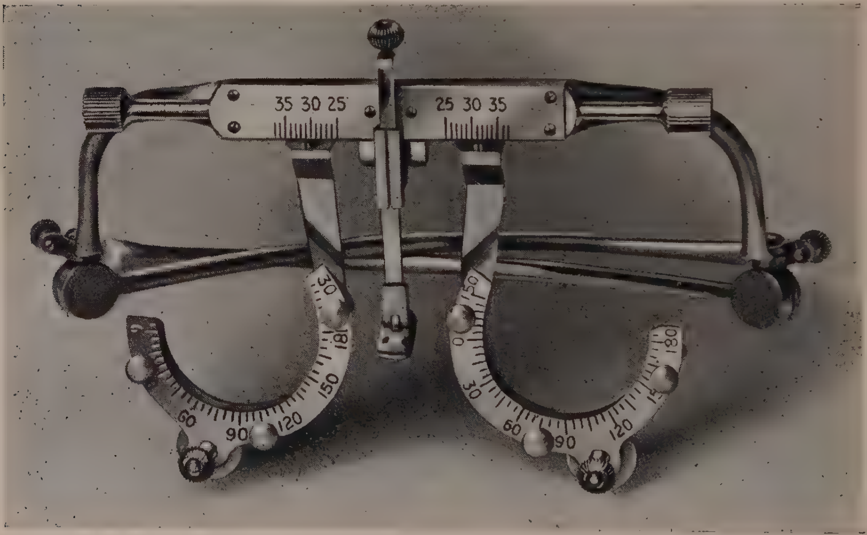


Figure 8. The Trial Frame

CHAPTER V

THE OPHTHALMOMETER

In so delicate a piece of work as is the exact measurement of the refraction, no help to this end is to be ignored or neglected. To the expert is given by the visual acuity test, both before and after cycloplegia, clues to the presence or absence of astigmia and in a measure, the degree of any associate ametropia which may be present, but these are really hints rather than clues and are to be acted upon only in the light of exact data.

The optical principles upon which the opthalmometer is constructed are exceedingly simple. They are that the size of an image seen in reflection from a convex mirror depends upon, first, the size of the luminous object and, second, its distance from the mirror. If the latter two constants are fixed, then the size of the reflection is commensurate with the greater or lesser convexity of the mirror. The telescope of the instrument is focussed to give a clear image, at the eye piece, of the reflection from the cornea of the luminous objects, the mires, whose size is computed as giving a diameter of three millimeters when reflected from a cornea of average radius (7.8 millimeters). The light passing through a birefringent prism doubles these images but the outer two are disregarded. The reader is assumed to have a knowledge of how the instrument is manipulated. It is evident that the higher the dioptric power of the corneal curve, the smaller will be the reflected images, so, to bring these in apposition the mires must be placed further apart.

Here is the first fact of value. For example, if the corneal curve indicates a refractive power of between forty-nine and fifty diopters and the refraction subjectively is emmetropia, the indication is that we have a short axial length and an undeveloped eye. If a myopia of from four to five diopters is revealed, this indicates a congenital curvature ametropia, neither progressive nor pathologic, which usually remains constant through life. On the other hand, a low power cornea, say of thirty-nine diopters with from five to six diopters of hyperopia is not an axial ametropia. Should such eyes accept no correction, it means an elongation of the optic axis and beginning myopia.

Suppose one eye has a thirty-nine diopter power and the other a forty-four. In this case a plus 1.00 over the higher and a plus 5.50 over the lower is accepted. Inasmuch as the focal points in both eyes are the same distance from the cornea, this difference in power does not give unequal sized retinal images, and the patient can wear nearly or quite the full correction. The conventional allowance of only 1.50 diopter between lens powers is merely a convention and may be often violated. The factor of discomfort is not elicited in these cases except in oblique vision and here the disturbance is due to prismatic effects. This will be taken up at length in dealing with high anisometropia. What the ophthalmometer does is to measure with exactitude the radii of curvature and the powers of the cornea in both horizontal and vertical meridia. If there is a difference, the eye is astigmic and the axes of greatest and least refraction are also indicated. This does not mean that the patient necessarily will accept a cylinder at the axis or of the power so indicated—sectorial

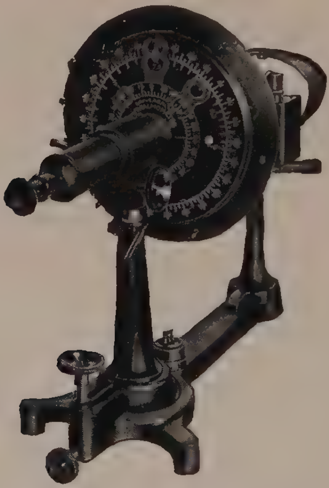


Figure 9. The Ophthalmometer

spasm of the ciliary muscle, obliquity of the plane of the lens, or sectors of unequal refraction therein may modify the findings. But, if there is a marked discrepancy, it devolves upon the refractionist to know why.

It can happen that the axes of greater or least refraction are not exactly at right angles. In this event the cylinder may be accepted at one or the other but not at an intermediate axis. It is not to be forgotten that the instrument measures the curvatures of the cornea at its surface. Now we cannot wear lenses in contact with the eye. They must be removed from this point and the amount of removal increases, if plus or decreases if minus, the power of the cylinder. Allowance must be made for this and furthermore an association with a high axial error either hyperopia or myopia makes still greater differences. For instance 3.00 diopters of astigmia at the cornea with 5.00 diopters of hyperopia, at the distance at which glasses are usually worn, is equal to a 2.50 diopter cylinder and with 5.00 diopters of myopia it is a 3.50 diopter. If, for any reason, the trial frame is set further out or it is wished to set the spectacle lenses closer in, there is a very simple rule by which the powers may be calculated and which will be given in its proper place. Only with a clear cornea can sharply defined reflections be obtained.

A faint stippling, either of the epithelium or on Bowman's membrane, too little to be seen with the naked eye, shows up at once in the miral reflex and not only suggests pathology but explains why the vision can not be brought up to normal.

In the scarred cornea due to any type of keratitis, the ophthalmometer is invaluable. The patient's vision may be so poor that even large differences in the correcting lenses are inappreciable but the datum obtained by the instrument will determine largely the power and axis of the cylinder. Beginning conical cornea shows at once for it is impossible in this condition to bring the central marks on the mires into a continuous straight line.

Poor vision is a necessary concomitant to both these conditions but whatever corrective measures are possible are made easier of determination by the use of the instrument. He is a poor reasoner who bases conclusions on insufficient data. The ophthalmometer is not infallible, it must be used with the same substance with which the artist Opie mixed his colors—with brains, but any variation from the power or axis of the cylinder indicated by the instrument and that found subjectively has a satisfactory explanation if sought for with skill and diligence. For example, it must not be forgotten that the eye under cover is still converging and that the eye undergoing examination tends to take the position of repose. It does not follow therefore that the monocular axial findings in the distance and the binocular functioning in the near are necessarily identical.

The refractionist is born, not made. He requires so large a measure of tact, intuition, patience, kindliness and wisdom that even the chosen few can hope to attain no more than an approximation to perfection. But even if he should possess all these gifts of the gods, he is foredoomed to failure if he elects to work with imperfect or inadequate equipment.

Nothing can be of greater influence than is the psychic reflex upon the operator from his surroundings. Listen to the wisdom of Hafiz. "Things re-act, and sometimes greatly, on the soul. We cannot live in a vacuum. There are inescapable relationships between possession and personality. Not a little of our sense of self gathers around and grows out of that which belongs to us."

Apparatus bought only to make a brave show or with the intent of creating an impression of efficiency—not sustained by performance—is pure charlatanry and makes a charlatan of him who owns it. The possession of exquisite tools does not make a mechanic, but it does make a good mechanic proud of his possessions, of himself, and of his efficiency through them. Whatever handicaps performance handicaps personality, and conversely the consciousness of possessing perfect equipment is a constant spur to higher achievement.

Now have been given details of a proper background and the essentials in equipment without which accuracy embodying the refinements of refraction work is impossible. The big guns bear the brunt of the battle but it needs the small arms to mop up the remaining units. These side-arms are the cross-cylinders, small in compass—but of infinite value in the closing of little gaps in the offiensive.*

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*The apparatus described herein is made by the Shur-On Standard Optical Co., Geneva, N. Y.

CHAPTER VI

THE CROSS-CYLINDER

After the refraction has been roughed out, objectively and subjectively, the final finish is attained by the cross-cylinders. They are made by crossing a plus and minus cylinder at right angles, or, what optically corresponds to the same thing, grinding a plus cylinder of greater power on a minus sphere. For example, if a plus 1.00 diopter cylinder is ground on one side of the lens and a minus 0.50 diopter sphere on the other, the effect is of a plus 0.50 cylinder at one axis and a minus 0.50 cylinder at the other.

For greater or lesser strengths the ratio is the same, the cylinder is twice the power of the sphere. The position of the axes, and the power is etched on one side of the lens. When such a lens is placed before the naked eye, say a 0.50 on a 0.50—you get a minus 0.50 on a plus 1.00 cylinder, or a plus 0.50 on a minus 1.00 cylinder. The lenses are alike but the powers are transposed.

In working with the cross-cylinder, what makes for confusion to the beginner is a lack of familiarity with the rule for transpositions, or from not understanding what happens when cross-cylinder additions are made to a tentative correction already before the eye.

The rule for transpositions is simplicity itself. For the new lens form, retain power of cylinder but change the sign and invert the axis; for the new sphere, add algebraically the powers of the old sphere and cylinder.

As examples, a plus 1 diopter sphere combined with a plus 1.00 diopter cylinder, axis 90, is equivalent to a minus 1.00 diopter cylinder, axis 180, combined with a plus 2.00 sphere; or again, a plus 2.00 diopter sphere combined with a minus 3.00 diopter cylinder, axis 180, is equal to a minus 1.00 diopter sphere combined with a plus 3.00 diopter cylinder, axis 90. (Adding plus 2.00 and minus 3.00 equals minus 1.00.)

In other words, powers of like sign take on increment, of unlike signs suffer decrement. The examples given apply to flat lenses; to ophthalmic lenses ground in toric form another factor, periscopy, enters, which will be elaborated in its proper place.

To grasp readily what happens when a cross cylinder is placed over a tentative correction, one should work out in graphic form the optical effect on different forms of spherocylindric combinations, for example: a plus 1.00 diopter sphere may be represented as a cross, opposite each arm of which is placed a plus 1.00 sign. In other words, horizontal and vertical meridia are of equal power. A plus 1 diopter cylinder, axis 90, is represented by a cross, the horizontal arm carrying the plus 1 mark, the vertical the sign of zero. (Light passing through a cylinder suffers no refraction along its axis.) A combination of this plus sphere and plus cylinder may be rendered by a cross, the vertical arm carrying the plus 1.00 sign, the horizontal a plus 2.00. That is to say, the powers of each meridian are added together.

A cross cylinder has its minus axis marked in red, its plus axis in white and its power etched opposite these axes. Optically, when the plus marker is held vertically, it adds to the dioptric value of the horizontal, and decreases the value of the vertical. If in the example just given, say a crossed 0.25 is held so the plus axes are coincident, then the cylinder is increased and the sphere diminished. This may be represented graphically by a cross whose vertical arm carries a power of plus 0.75, and the horizontal a power of plus 2.25. Taking the power of least refraction for the new sphere, and the difference for the new cylinder, we have a plus 0.75 sphere combined with a plus 1.50 cylinder. If the cross-cylinder be superposed with its plus axis at right angles to the cylinder of the tentative correction, then the cylinder is reduced and the sphere increased.

Graphically this is a cross with the vertical arm of plus 1.25 diopters and the horizontal of plus 1.75 diopters. Applying the same rule, the resultant combination is a plus 1.25 sphere and a plus 0.50 cylinder. In both cases spheric and cylindric values have been modified and where cylinder is decreased, sphere is increased and vice versa.

The same modifying factors are operative and to the same degree in minus on minus combinations, but with combinations of opposite signs, the results are different. Now both powers are increased or both diminished. For example, the tentative correction is a minus 1.00 sphere combined with a plus 2.00 cylinder, axis 90. Graphically this is a cross with the vertical arm having a power of minus 1.00, the horizontal with a power of plus 1.00. Superposing the crossed 0.25's with plus axes coincident, the resultant combination is represented by a cross, the vertical arm having a power of minus 1.25, the horizontal of plus 1.25. Taking the lesser power for the sphere, and the difference (algebraically) for the cylinder, the result is a minus 1.25 sphere combined with a plus 2.50 cylinder, and thus both powers have been increased; or, if the crossed 0.25's be superposed with cylinder of same sign at right angles, the result is a lens whose power vertically is minus 0.75 and horizontally plus 0.75; transposing, this gives a minus 0.75 sphere combined with a plus 1.50 cylinder, and thus both powers have been diminished.

The thing to be remembered is that cylinders of same sign superposed at parallel axes increase the power of the cylinder before the eye; at right angles diminish the refractive value. With this, and the effect on the sphere memorized, working with the cross-cylinder quickly becomes a matter of unconscious cerebration and changes suggest themselves without conscious effort. A working battery of cross cylinders are four in number: a 0.12 on a 0.12, a 0.25 on a 0.25, a 0.50 on a 0.50 and a 1.00 on a 1.00.

CHAPTER VII

TAKING THE VISUAL ACUITY

It is understood that pathologic conditions are not under consideration but only visual disturbances incident to errors of refraction.

Technique in this and succeeding chapters is based on the use of the illuminated test card or the transilluminated test cabinet, mostly the latter, the visual graduations computed in percentages. One might think that no skill would be required to find out how much a patient can see. On the contrary, there enter in the psychic factor and personal equation to complicate the problem. Some patients are so anxious to make a good showing that they will attempt a line where the letter forms are so blurred that they simply guess from the outlines what the letters may be, and it is surprising how often they guess right. On the other hand, they may come from Missouri and their mental attitude may be, "My sight is poor—prove to me you can make it better." These patients will stop when the line below can be read although perhaps not readily.

No accurate conclusions can be drawn from inadequate data, and much valuable information may be obtained, first, by the manner in which the chart is read, whether scanningly or with speed and surety, and second, whether the Z's and the B's are as easily seen as the A's and the V's, or if the C's and the O's are readily differentiated. Let me illustrate by concrete examples as to how much may be inferred from the visual acuity test. Let us say a child of ten years can read fluently the sixty per cent. line without hesitating on the confusion letters but none of the seventy per cent. line are visible even upon urging that an attempt be made. The condition cannot be manifest hyperopia of low degree else the urge would bring out for an instant a letter or two in this line. Any astigmia present, if of considerable degree would cause hesitation at the B's and Z's. The age of the child implies an active accommodation but even if suspended, in an emmetropic eyes, this would show only in the near with normal acuity in the distance. Also we know that myopia begins about this age and we know also that for each one-tenth visual loss there is an approximate refractive error of 0.25 diopter. With forty per cent. missing the error is about 1.00 diopter. The inference is that the child is myopic and to this degree. Spasm of accommodation is a remote possibility but this rarely holds steadily at 1 diopter, vision fluctuates.

Let us take another child of same age who has one hundred per cent. vision but who stumbles on the line, hesitates and the next instant reads less than before. The inference now is that the child has a hyperopia more or less latent with an added astigmia. Or again, say the child can pick out the A's and the O's on the fifty per cent. line and possibly a V on the next. It is inferable now that the error is largely astigmic with little axial ametropia. Within limits the same reasoning applies during adolescence and early manhood.

The tests are made at twenty feet, or its equivalent, by reflection from a mirror at ten, so that the accommodative power exercised is only one-sixth diopter and is a negligible factor so far as the distance acuity is concerned, unless either old age has nearly abrogated accommodation or that, in the young, it is being called upon for excessive action.

Visual acuity of one hundred and fifty per cent. in the child is no criterion of the refractive error. There may be a most damaging ametropia (latent hyperopia) without symptoms referable to the eye itself. In this place I say nothing of reflex disturbances and all one can know from the test is that myopia or myopic astigmia cannot be present.

Low visual acuity indicates high error, less than one-tenth means that at least 2.25 diopter will be needed to correct and this may be in both meridia or in one only. By this I mean 2.25 sphere or same power cylinder or a combination of both. In the young probably minus, in the old probably plus. In patients past middle age who heretofore have gone unglassed the error is almost always manifest hyperopia with an associate astigmic error of low degree. Why this is so will be explained later.

In taking the visual acuity let both eyes be uncovered and do not put on the trial frame yet. First turn on the illumination of the one hundred and fifty per cent. line only. Do not ask if the patient can read this but instead, "Can you pick out a single letter on this line?" If "no" is the answer, turn off the light on the finer type, and then turn it on to the one hundred per cent. line with the same query. So proceed in coarser gradations until the answer is, "Yes, I can read all the letters" or "I can pick out certain of these," specifying which ones.

Rarely do all the letters come simultaneously into view for this would imply simple myopia without astigmia. In my experience less than one-twentieth of one per cent. of all eyes tested were free from astigmia in one or both. Let us say the affirmative answer comes on the sixty per cent line. Now cover (with the record card) the left eye. If the letters are still visible, shift the cover to the right. If visible still, record both eyes as having sixty per cent. If not, (keeping the right covered) turn on lesser percentages until "Yes" again becomes the answer. Say this is at forty per cent—now the vision is determined for both eyes separately right eye, sixty per cent—left eye, forty per cent. The reason why the trial frame is not put on at this stage of the game is that time is lost, nothing gained and should it so happen that the patient has little or no vision in one eye, without being aware of it, he may think that what you have done has impaired his sight. Do not think that this is an extravagant notion. It has happened more than once and the occurrence does not add to the gaiety of nations or to the equanimity of the refractionist.

CHAPTER VIII

THE PSYCHOLOGY OF REFRACTION WORK

It matters not how immutable may be the laws of optics as applied to inanimate things, they cannot be rigidly applied to the living eye. There are too many variants, too many factors, both mental and physical to make their application to refraction work mathematically exact. In other words, while the laws of refraction must ever rest on a scientific basis, the application of these is purely an art.

In the first place, no one can do good refraction work if he is in a hurry. As a preliminary, I recommend to the beginner Sir William Osler's essay on "Equanimitas." Repose of mind and body are essentials to patient and operator. Any haste, disquietude or impatience is felt, perhaps unconsciously, by the patient and is a telepathic barrier to the necessary establishment of mutual and cordial relationships. One must see out of his patient's eyes, must appreciate what goes on both inside and behind the orbits. Vision is not a function of the eye, it is purely cerebral. A camera is only a box unless loaded with a sensitized plate and while the analogy lacks something of conformity, it requires brains to bring out the invisible image locked in the coating on the film. From perception to apperception the visual concept must travel through devious channels and to find expression in motor speech, many more. It is interesting to watch the facial muscles between these interludes and note how they respond to the cerebral impression. Long before the cloudy thought finds vocal utterance, the corners of the mouth register satisfaction, dissatisfaction or dubeity. The alert refractionist wastes no time over a lenticular change when either of the last two emotions appear on the surface. The dull, the stupid, the illiterate, the super-acute, the undecided, the embarrassed, present psychic complexes for analysis and solution. The dull must be prompted without being told, the stupid encouraged, the illiterate instructed, the super-acute repressed, the undecided forced to a decision, the embarrassed put at ease.

To put any lens, even a plano, before one eye belonging to any one of these types, and link it with that inane question "Is that better or worse?" is a confession of incompetency bordering on amentia. How can comparisons be established unless "good" is first registered in the cuneus, or before the methods and standards of perception are clarified.

All these things are apropos and a prerequisite to good refraction work and failing to give them their full value is to put a prohibitive handicap on accuracy. One must first establish contact and this needs the personal touch (no reference to the fee is intended). The refractionist is a liaison-officer between subject and object. The highest compliment ever paid me was when a patient said, "I can't see why I need an oculist, I seem to fit myself to glasses." The machine ran so smoothly that she did not hear the wheels go 'round. One must first establish in the patient the attitude of receptivity and an alert concentration of mind upon the business in hand. Once these are established, nothing must be permitted to disturb them. Patients who are prone to desultory talk must be tactfully repressed and those who respond to questions discursively must have their attention refocussed.

What I have said about the refraction room applies to refraction work. There must be nothing to distract the patient's attention and to sustain this, the operator must have his own mind concentrated on his work.

CHAPTER IX

CYCLOPLEGIA

I HAVE no quarrel with those who do not use cycloplegics. It is their method and if they and their patients are satisfied, why worry? However, this book is a record of personal experiences and from these I must hold to what they have taught me. My own procedure is that any patient who has evidence of eye strain (note this distinction) be he seven or seventy, shall always be refracted under full cycloplegia. This may seem an extreme position to take but twice have I lamentably failed, once at the age of 57 and again at 64, from neglecting to put the accommodation at rest. Moreover I was able to check up my mistakes in the refraction because the patients did not—as they justifiably might have done—change their oculist.

It is my opinion also that in the later decades of life with a small residuum of focussing power left, the need is even more urgent for cycloplegia.

Much has been said about the risk of inducing glaucoma in the aged. I do not think this need be a deterrent if even the simplest precautions be taken. In tens of thousands of cases it has never occurred in my hands, nor have I ever seen other harmful results follow. Never has been known a permanent impairment of accommodation although a lasting mydriasis has been reported by other workers. Personally I have never met with such a case. Systemic effects are nowadays unheard of. This was not true when duboisine, scopolamine, or hyoscine was employed as a cycloplegic. Atropine must be used with care especially in blondes, but beyond flushing of the face and dryness of the throat even this drug rarely does mischief. As I do not use atropine but homatropine exclusively, I have no casualties to report. It has been said that this latter drug is inefficient. It is not true. A series of many cases were refracted and then followed by the use of atropine for three days. There were no substantial differences between the two successive tests.

There are those who style an accommodative suspension as a "dead eye." With equal propriety would they consider a patient under general anaesthesia a corpse? Differences between the cycloplegic and the post-cycloplegic refraction have been cited as proof of the unreliability of the former. Such a contention argues for an unfamiliarity with the factors underlying these discrepancies. They are helpful rather than a hindrance to an appreciation of the ocular status. The explanation of them will be given under "The Post-Cycloplegic Refraction." Accommodative excess, manifest either to conceal a latent hyperopia or to exalt an accommodative spasm, cannot be unlocked without a cycloplegic. It is hardly necessary to comment on the harmful effects of either.

If, for no other reason than, the comforting assurance that the vision you get with lenses represents the static refraction of the eye and that no meddlesome vagary of the accommodation can interfere with this determination, should be enough argument for its use irrespective of the time factor. This is not a plea for the refractionist. He should not consider his own time or convenience but solely the welfare of the patient and this cannot be secured with one eye on the clock. This does not mean the patient's eye. Every eye, preliminary to cycloplegia, should be finger tested for a suspicious hypertension. One may become very expert in this expedient, within one or two degrees variation from the tonometer. So if any misgivings be awakened, the drug should be withheld pending the examinations of the fields and the fundi. To the trained observer, however, there is usually a sufficient turgescence of the deep perforating arteries to put him on his guard even before the tension is taken.

There are several cycloplegic drugs: Atropine, duboisine, scopolamine, daturine, and hyoscine. While very rarely poisonous in the doses used, nevertheless, their employment is not entirely devoid of risk. They may be dismissed from consideration here because only the first maintains any vogue and this only where convergent squint is accompanied or caused by latent hyperopia.

It is unfortunate that all these drugs are mydriatic as well as cycloplegic, because this introduces an unwanted complication—a dilated pupil. Glasses are given to correct the refraction in the pupillary zone only and the corneal periphery may have a positive or negative aberration which will alter both cylindric or spheric values, and make impossible the attainment, by glasses, of very acute vision at the time the refraction is determined under cycloplegia. Often is it seen that where only one hundred per cent was then possible, later one hundred and fifty per cent was secured and perhaps by a radical change in the lenses.

A very serious objection to the use of the above mentioned cycloplegics is the persistence of their effects over many days. It takes from ten days to two weeks for atropine to wear off. In former times, because of this, when atropine was practically the only drug used, there has grown up a tradition hard to combat. Often has it been said to me when "drops" were advised, "But, Doctor, won't these make me blind?" My question in rejoinder has been, "Do you think I would have any luck in fitting glasses to a blind eye?" Here is the time to reassure the patient and tell him, "You will see as well as you do now when you leave the office and only until to-morrow, will you have difficulty in reading." This is the strict truth. Homatropine is isomeric with atropine and differs only in action by being evanescent in its effects. Unneutralized, these last about 72 hours, mydriasis being the last to go. Being an isomer, homatropine is not stable. Old solutions lose the cycloplegic but still retain the mydriatic action. Solutions therefore must be freshly prepared. Homatropine used alone causes conjunctival congestion and is irritating. It must, therefore, be combined with cocaine. This drug relieves the congestion and acts synergistically with the other alkaloid. It is a convenience and better in every way to have the homatropine hydrobromide and cocaine hydrochloride, of each one-fiftieth grain, made up into small tablets one of which is applied to the lower and outer conjunctival sulcus, twice at thirty minutes interval. In a little over an hour satisfactory cycloplegia is attained. If, by any chance, contradictory responses to the refractive tests lead you to suspect imperfect relaxation of the ciliary muscle, put over the tentative correction a plus 3.00 diopter spheric lens and test out the reading power at 33 centimetres. If type can be approached to 25 centimetres without appreciable blur, too much accommodation remains, a third tablet should then be used and the tests resumed in another half hour.

After the refraction tests are completed, two drops of one-half per cent solution of eserine salicylate should be dropped in both eyes. This has no effect on the mydriasis but in twenty minutes, distance vision improves, if the patient is a hyperope, and in proportion as was the degree, is this improvement greater or less. In young subjects with high errors, the solution should be used twice and your patient sent out with your promise fulfilled that he should see as well as before. Don't forget to inform him of the twitching of the lids the drug causes or to remind him that reading is not feasible until the next day. While not wholly pertinent under this heading, a comforting attention is to lend the patient a pair of dark-smoke glasses. The pupil in mydriasis is not able to protect the eye against light excess and in full sunlight, glare is very distressing.

Cycloplegia and mydriasis are not always coincident phenomena. Sometimes, but rarely, homatropine will cause one without the other. Furthermore, complete mydriasis does not necessarily mean a total cycloplegia and a return to pupillary activity may be associated with a residual but slight temporary impairment of ciliary function.

To emphasize my contention for the need of cycloplegia, Hensen and Voelpers have demonstrated a segmental action of the ciliary muscle on irritation of a single fiber of the ciliary nerve, followed by the associate phenomena of accommodation, viz., advancement of the choroid and contraction of the pupil. This makes possible astigmic accommodation, makes for better vision in this ametropic condition and renders its subjective determination uncertain until the spasm is abrogated by cycloplegia.

A very distinguished physicist once told me that what I have just described was a physical impossibility and that what has been called astigmic accommodation is simply astigmic adaptation, a mental rather than a physical phenomenon. He explained that the individual having an astigmia with an hyperopic element shortened his focal interval to the greatest possible degree, and then through a mental concept translated the blurred images into shapes that could be defined. In refutation it can be shown by retinoscopy that astigmic accommodation surely exists and that plus cylinders subjectively accepted and giving maximal vision in the non-cycloplegic state are nevertheless an undercorrection.

There is only one logical deduction from this datum—a segmental spasm of the ciliary muscle induced by long continued habit. Astigmic accommodation is difficult of comprehension as is also the mechanism of dynamic increase in the refraction. To my mind the theory of Helmholtz is lacking in reasonableness. I cannot conceive of so exquisite an adjustment dependent upon a negative action or that, in repose, there must exist zonular tension. That the lens shall assume a toroidal surface to neutralize a corneal curve seems less reasonable than a segmental action of the ciliary muscle to tilt the lens upon an axis coincident with the meridian of least refraction. What abnormal ciliary activity does to the nutrition of the globe can only be surmised but that its influence is harmful is evidenced by congested eyes, swollen lids, and not infrequently by the development of cataract. Every skilled refractionist can cite cases to show how a painstaking exactitude in correcting a refraction can delay or prevent the further progress of incipient lenticular opacities.

CHAPTER X

THE ROUTINE OF REFRACTION WORK

After having determined the visual acuity in both eyes, tested separately, this is respectively recorded at its proper fraction, *e.g.*—vision right eye equals fifty per cent. vision left eye equals forty per cent. or whatever else it may be. The next step is the estimation of the corneal curves by the ophthalmometer. This also is recorded. It is better to indicate graphically dioptric power rather than simply the amount of astigmia, *e.g.*—if in the horizontal meridian the mires are in contact when the indicator stands at 45 diopters and in the vertical it registers 47 diopters this means a high power cornea with 2 diopters of astigmia. If you put down 2 diopters with the rule you have overlooked a pregnant fact. Record it thus: vertical 45, horizontal 47; or it can be 43 diopters horizontally and 45 diopters vertically and is indicated thus: a cross with 43 opposite the vertical arm and 45 opposite the horizonal. This means a low power cornea but the astigmia is still 2 diopters with the rule. In the first instance a minus 2.00 diopter cylinder at 180 suggests itself, in the other a plus 2.00 diopter cylinder at 90. These, in the instances cited, convert both meridia to 45 diopters which is about the average of many measurements. However, as the ophthalmometer takes no cognizance of axial measurements, it is better to assume that it is the plus cylinder that is needed and to begin with this. The opthalmometer tells you something more than the differences in corneal radii. A brilliant undistorted reflex is not usually compatible with pathology, although old corneal irregularities in the deeper layers may not show in the miral reflections but only when viewed with the plane mirror used at two or three feet and with light reflected at an angle. These irregularities show best if the patient successively looks up, down, right and left.

With the visual acuity and the corneal curves recorded, you proceed to the first approximate estimate of the refraction. If, as in the cases cited, 2 diopters of astigmia is indicated, put on a plus 2 diopter cylinder at 90. With this amount of error vision must necessarily be low, say about twenty per cent. If the cylinder is accepted and by this is meant no impairment but rather an improvement, place over this successively plus and minus 1 diopter spheres. With such poor vision it is not worth while beginning with lesser powers. Note the result. Whichever improves keep on adding higher powers of same sign until nothing more can be gained. If plus cylinder is *accepted*, it is certain that it can not be myopic or compound myopic astigmia, but it may be mixed. If so, probably an equal division of the powers minus 1.00 vertically, plus 1.00 horizontally. If plus spheres over the cylinder increase visual acuity, then it is compound hyperopic. After the best results are attained, juggle with the cross cylinders for any change needed in the power of the cylinder, and try out changes in the axis. With a plus 2 diopter cylinder even slight changes in this are readily appreciable. Take hold of the trial frame at the end piece and tilt the cell up or down. If up improves the vision, cylinder axis goes to the patient's left; if down, to the right. It is better to do this before determining cylinder power. If your ophthalmometer shows slight differences (say 0.25 diopter) it is hardly worth while (at this stage) to consider cylinders at all. If vision is good, say one hundred per cent. nothing is gained by precycloplegic tests and time uselessly wasted in experimenting with lenses. If with the same low corneal curves vision is poor, say 40 per cent it is an axial ametropia; myopia in the young, latent hyperopia in the aged or some pathology. Try out plus and minus 1.50 diopter sphere. If no improvement with either, try the pinhole disc. If this fails also there is certainly some disease of the eye. Only in this event is the ophthalmoscope to be used *before* refracting.

The study of the eye grounds is not a thing for a glance. Level, margins, color, vessels must be studied on the disc, lack of clarity in the media, pigmentations, absorptions, deposits in the chorio-retinal structures, and when all this has been done the glare has induced a retinal fatigue incompatible with acute discrimination between lenses.

For this reason, in non-pathologic cases, ophthalmoscopy is the last procedure in the ocular examination.

If a tentative lenticular correction has been found now is the time—-with this in place—to measure in each eye separately and then binocularly the amplitude of accommodation. Methods and conclusions from the findings will be given in a later chapter. The cycloplegic is now used and when the patient is fully under its influence, the *serious* business of refraction work begins.

CHAPTER XI

THE CYCLOPLEGIC CORRECTION

Much can be learned as to the refractive condition of the eye by the way it behaves under cycloplegia. If before inducing this, vision was high, say one hundred per cent and after, it drops to say, twenty per cent, it indicates a hyperopia of about 2.00 diopters. While not mathematically exact it is a good working rule, that for every 10 per cent difference plus 0.25 is needed to correct. The rule is, subtract from one hundred per cent the amount shown under cycloplegia and multiply the difference by 0.25. This represents the hyperopic error in one or both meridia, *e.g.*—it may be a plus 2.00 diopter sphere or plus 1.50 diopter sphere combined with plus 0.50 diopter cylinder or plus 1.00 diopter sphere combined with plus 1.00 diopter cylinder. An immediate response follows the use of the higher sphere. Still, if vision does not come up to one hundred per cent but varies around sixty to seventy, we know that there is more or less astigmia. If minor changes in the sphere (plus 0.25 or minus 0.25 diopter sphere) do not improve vision, resort is at once made to the cross cylinder. If only sixty per cent has been attained, the cross 0.50 on 0.50 is used. If the ophthalmometer has shown an astigmia with the rule, it is better practice to start with the plus axis at one hundred and eighty degrees. After a moment or two, to let the visual effect register, the axes are reversed and the plus is placed vertically. The contrast is so marked that the patient has no hesitancy in his choice. At this stage one may swing the axis, through an arc of thirty degrees, fifteen either side of ninety degrees, allowing an interval for the patient to decide if any improvement results from the positions at seventy-five or one hundred and five. It is a curious fact that if cylinder axes do vary from verticality (the usual plus position) or horizontality (the usual minus axis) they do so commonly in multiples of 15, and opposite to each other. Thus, if in one eye the axis is seventy-five, it will be one hundred and five in the other, or it may be sixty in one and one hundred and twenty in the other. It will usually be found that the sum of these axes is one hundred and eighty. There are too many exceptions to make this invariable but it is a good working hypothesis. Cylinder axes inclining in the same plane are rarely found, *i. e.*, both at seventy-five or one hundred and five. One axis at ninety and the other at one of these others is common.

Occasionally we get a right-angled error, one at say, fifteen and the other at one hundred and five. In the majority of these anomalies, the difference is ninety and the sum is not one hundred and eighty. In proportion, as an approximation to one hundred per cent is obtained by spheres so is suggested the weaker cross cylinder. If ninety per cent vision is gained, then the 0.25 is used and in the same manner as is the stronger one.

Nothing is so fatal to refractive accuracy as is the assumption that one hundred per cent indicates perfect vision. This attained on the test chart may be compatible with glaring errors. We should assume as our goal two hundred per cent. If vision under cycloplegia is not changed from that ascertained before its inception, the first thought is mixed astigmia. If sight is improved there is certainly a myopic preponderance either in sphere or cylinder and proportionate to the difference from the non-cycloplegic findings is this greater or less. Of all difficult cases none are more so than those in which vision before and after taking remains constant at one hundred per cent. If the standard has been set at this the inference might be that there was no refractive error at all. What we should infer is that one hundred per cent is subnormal for this patient. The error is surely small but just because of this it becomes the more imperative that it shall be found and corrected. Large errors cause only poor vision, small ones cause eye strain and damaging reflex disturbances. The smaller the error, the more difficult is its detection.

While the technique of the cycloplegic correction remains the same it differs in degree only as the error is manifestly greater or less. In the last case cited, the one of greatest difficulty, it is not possible that this is a myopic error for the cycloplegic did not improve vision. It cannot be hyperopic to any considerable degree for vision was *not* impaired by its use. There remains only a low hyperopia, a low miopia or a minor mixed astigmia. How shall we determine which? Now all cycloplegic corrections begin with the sphere. Leaving illuminated the one hundred per cent and one hundred and fifty per cent lines, we place in the trial frame over the uncovered eye a plus 0.25 diopter sphere. Directing the patient's attention to the one hundred per cent. line, but only to one letter upon it, and that the most difficult of perception, say Z, we ask, "Do you see now that letter *as well* with it or without it?" At the last phrase the lens is removed. Note, we do not ask is it better or worse. If the patient sees as well, we slip this lens into the cell on the trial frame and add another plus 0.25 diopter sphere, asking the same question—"Do you see as well?" Now it is strongly presumptive that the answer will be "No." If it is "Yes," we ask, "Does the letter appear larger or smaller?" Usually the answer is "larger." This means an overcorrection—the focus has been thrown in front of the retina. Taking off the later addition, leaving on the plus 0.25, we ask, "Can you pick out a single letter on the lower line?" If "no" we take off the sphere and ask again; if still "no" the sphere is replaced and the 0.25 on the 0.25 cross cylinder is brought into play.

With so good a visual acuity, the ophthalmometer findings will not be conclusive. It is altogether unlikely that the astigmic error is 0.50 diopter but with an overcorrection of the cylindric error, axis is the more readily determined. With the plus element at one hundred and eighty degrees, again attention is directed to the *lower* line. If no letter stands out, the plus element is turned into the ninety degree position. Still if no letter appears, axes at 45 and 135 are alternately tried. If no difference is detectable, we may conclude that both meridia are out of focus. We now take off the plus 0.25 diopter sphere and go over the same procedure with the same cross cylinder and now if there be any refractive error, one of the positions will bring out one or more *easy* letters on the one hundred and fifty per cent. line. Let us say when the plus element stands at 45. In the case that is under consideration, oblique astigmia is more likely than one with symmetrical axis. Swinging the plus axis into 30 and 60 respectively perhaps we find the thirty degree position gives slightly better vision. We now put on a plus 0.25

diopter cylinder at 30 and perhaps most of the letters become visible. Whenever a cylindric lens is accepted, weak plus and minus spheres should be alternately superposed. In this case the plus sphere blurs, but the minus sphere brings out all the letters. We have now found the correction and we put on record: Vision equals one hundred and fifty per cent. with minus 0.25 diopter cylinder axis 120. With larger errors the problem is easier of solution. The technique is always the same—obtain the best vision possible with the *weakest* plus or minus spheres before employing cylinders. If say with ten per cent vision a plus 1 diopter sphere is *accepted* only, begin with the crossed 1.00 on a 1.00. With cylindric errors of 2.00 diopters the response is immediate, when the proper axis is reached.

If the ophthalmometer has shown this amount or more, time will be conserved by starting with a plus cylinder at the axis indicated, testing, for appropriate spheres, first of one sign, then of the other until perfect, or the best possible vision is obtained. When only ten per cent vision remains to the eye under cycloplegia and neither a plus 2.00 diopter sphere nor a minus 2.00 diopter sphere has any effect, you may be sure you are dealing with a high astigmic error. In these cases the ophthalmometer is invaluable. If your spheres give you ninety per cent vision, the cylindric error is around 0.25, if eighty per cent, around 0.50, if seventy per cent around 0.75, and if sixty per cent around 1.00. The same rule applies to cylinders as well as to spheres, 0.25 for each ten per cent missing from entity. There can be no accuracy in refraction work unless and until an entente cordiale is established between the refractionist and the patient. Talleyrand said that "words were given us to conceal our thoughts." This might apply to the diplomatist but it does not to the doctor. It is his choice of words which makes the difference between success or failure. To turn on all the lights and ask, "What do you read?" has often evoked the answer, "Nothing, Doctor, except the daily papers." Now you have a loose contact with the engine missing on all six cylinders, to say nothing of the spheres.

When our cycloplegic patient begins to stutter on the sixty per cent line, it is time to be more specific in the questionnaire and to get closer contact psychically. If the case is hyperopic (and by this is meant a plus acceptance in sphere cylinder or both), the question is, with each lenticular addition, referring to a letter and not to a line, "Do you see as well with this or without it?" not "Is this letter seen better or worse?" and emphatically not "Is this better?" When the spheric addition fails to *improve* or at least makes vision no worse, recourse is had to cylinders. Always with the hyperope must "as well' take the place of "better." To the myope the questions are reversed. As vision approaches perfection, the questions become still more specific. Let us say, some (the confusion letters) are indistinct or illegible. Now the patient is prompted as to what should be the correct answer. Telling the patient to fix on the fourth letter (say this is an F)—often they call this a lower case "r" or a "p"—you say the fourth letter is an "F" and making small changes in sphere or cylinder, you ask, "Do any of these changes bring this letter out as an "F?" If one of them does, the lenses so chosen are put into the trial frame and we work back to the former correction to ascertain which is the better and if the influence of suggestion may have determined an incorrect conclusion. It must not be forgotten that the cycloplegic correction often falls short of the sharpness of vision which will be obtained in the post-cycloplegic refraction and that the disturbing factors, glare and peripheral aberrations incident to dilated pupils will have to be reckoned with later.

In testing out myopes, the question changes to "Can you see any letters on the next line with this?" Not "Do you see as well?" for there may be sufficient residual accommodation remaining to permit an affirmative answer. With this difference in interrogation, we proceed with myopes the same as hyperopes. Perfection is a matter of trifles but perfection is no trifle and it cannot be obtained by ignoring little things. With an eye under cycloplegia, differences of 0.25 diopter sphere in power or even less in cylinders are as readily differentiated as are larger values, and an error of five degrees even in a 0.25 diopter cylinder is inexcusable. You can tell by the patient's answers and above all by the expression if you are in accord; and, if not, make the question different until you feel your meaning is wholly understood, insisting always upon particular definition of the object looked at without permitting diffuseness of either sight or attention. Above all do not interject desultory conversation to distract from the seriousness of the business in hand.

What always complicates the cycloplegic correction is the lack of conformity of the corneal curves in the pupillary zone and that peripheral to it. With a dilated pupil we take in areas unused under normal conditions and must reckon with aberrations always spheric and often astigmic. These errors may be partially eliminated and made less confusing if we slip an opaque disc, with a four millimetre aperture into the back cell of the trial frame and work out the refraction in the uncovered area.

CHAPTER XII

THE AMETROPE

The ametropias may be grouped into three divisions and sub-divisions. We might premise that there is no such thing as an emmetropic eye, approximately yes, absolutely, no. That the minor ametropias, or even the major may be harmless is beside the question. An astigmic laborer with two diopter of error may not be aware at all of any visual disability. A student with 0.25 diopter may have his usefulness crippled and his comfort wrecked by it. In the latter case an incorrection means disaster. The student who has two diopters of astigmic error, while handicapped by poor vision may not suffer, but an error of 0.25 in his glasses either side of lenticular exactitude or five degrees in axial displacement will convert a mere visual defect into a most exasperating ametropia.

There are social and economic factors indissolubly linked with every form of ametropia. You will not find any myopes among the juvenile delinquents nor any hyperopes among introspective, morbid, and solitary children. I trust my readers may pardon this digression but it is of far reaching import and emphasizes the importance of accurate refraction work. All forms of ametropia, in major part, are axial or curvature anomalies. Hyperopia means a short eyeball, myopia a long one; astigmia a toric cornea. From these, alone or in combination, are all forms evolved.

Hyperopia with astigmia is the commonest defect in this country. In my experience simple hyperopia is a very rare condition. Failure to find any astigmic association usually means incompletion in examination or a lack of skill in measuring minute errors. The mistake usually is consequent to placing the visual standard too low. One hundred per cent should be regarded as average and not as perfect vision.

No ametropic condition presents insuperable difficulties under cycloplegia, and hyperopia the least of all. Understand that only static errors are being considered now, that

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only errors of refraction come under this heading and that the intricate problem of the post-cycloplegic correction has yet to be solved.

One striking phenomenon stands out in the hyperope with the ciliary muscle out of action, and that is the great disparity between the visual acuity before and after inducing this inaction. A hyperope of three diopters or more has less than ten per cent vision remaining, irrespective of what might have been the pre-cycloplegic acuity. Proportional to the degree of the hyperopia is the amount of visual impairment. If this is recorded as less than ten per cent begin with plus 2.50 diopter sphere.

The ophthalmometer has already given you a clue as to the cylindric error. If this is very high, 2.50 diopters or more, begin with the cylinder at the axis indicated by the instrument. If low, from 0.50 to 1.00 diopter, begin with the sphere. When one of the focal planes falls exactly on the retina, then it is that the cross cylinder is most effective, so before calling this into use, attain the maximal vision with the least powered sphere. This applies to a myopic error as well. The ophthalmometer has given a clue but the improvement possible with spheres gives another. If only forty per cent vision is possible, begin with the crossed 1.00 cylinder, if sixty per cent try the crossed 0.50 cylinder, if eighty per cent then the crossed 0.25 cylinder. The crossed 0.12 cylinder is reserved for the final and finer estimation of the astigmic error. A good working rule in refractive errors of any type, with the eye under cycloplegia is: Begin first with a sphere, strong if the vision is low; weak if it is high, and remembering that every ten per cent lacking represents approximately an error of 0.25 diopter, the selection of this sphere is simply a matter of mental arithmetic. Only with very high ophthalmometric findings are cylinders used first. When maximal vision is obtained, only then are cylinders superposed on the spheric addition. The primal function of the crossed cylinder is *not* the determination of an astigmic error but to institute comparison between cylindric powers already before the eye. With same signs at parallel axes, increase is effected, at opposite axes decrease. At the same time, however, spheric powers are modified, so after any change made, either greater or less in the cylinder, the effect of superposed weak plus or minus spheres must first be tried before proceeding further. Often with a high plus error one must be satisfied with less than one hundred and fifty per cent vision. The peripheral aberration of the biconvex correction, the asymmetric corneal curves, and the glare, incident to a dilated pupil, all militate against sharp focal definition; but in spite of all this the basic refraction and particularly the axial error are determined within a minimal error and afford a sure foundation upon which to formulate the post-cycloplegic prescription.

CHAPTER XIII

THE MYOPE

The myope presents an entirely different problem from the hyperope. The cycloplegia is not an annoyance to the near-sighted as his distance vision is not impaired unless his peripheral corneal aberration is high. Usually he sees better after than before ciliary inaction is induced and if he have 3.00 diopters or more of error, he can still read comfortably at his punctum remotum. Moreover his post cycloplegic correction is a matter presenting only minor difficulties uncomplicated by the factors which enter into, and make onerous, refraction in the hyperope.

Hyperopia is a developmental and congenital defect. Myopia is one acquired and carries with it a suspicion, at least, of morbidity. Only very rarely does one find a curvature myopia with a cornea of seven millimetre radius or less. Among many thousands once only have I met with such. Of course this is congenital, stationary and is never pathologic. It is my opinion that the future safety of the myope depends upon wearing his full correction constantly. What this correction is can be determined only under full cycloplegia. There should never be any post cycloplegic change from the axial error so found unless the patient's occupation demands much outdoor work. In this case, minus 0.25 diopter should be added. Of course at the 20 foot distance the myope is always undercorrected by 0.16 diopter. Acquired myopia dates from about the ninth year of life. Fortunately in this day of compulsory education and periodic school tests of the pupil's vision, the condition is detected early, even so little as 1.00 diopter of error makes blackboard work impossible.

The punctum remotum is at 40 inches and beyond this clear vision is impossible. It makes all the difference in the world if the myope goes unglassed until adolescence is left behind. Now his ciliary activity has fallen into a condition of innocuous desuetude (to use Grover Cleveland's famous phrase) and the problem is complicated by accommodative inertia. It has been stated that an available accommodation equal to two-thirds of the amount to be used is enough for comfortable continuous use, *e.g.* working at thirty-three centimeters, 4.5 diopters should be sufficient for one's needs.

This is not true. What one does need is two-thirds of the mean accommodation proper for the age. A man of 43 whose mean accommodation for his years is 4.5 diopters can use his eyes comfortably for close work without added plus spheres. A patient aged 25 with an equal amount (4.5 diopters) cannot read at all and has blurred and painful vision. His mean accommodation at that age should be around 9.00 diopters and he needs 6.00 diopters for close work. The myope is usually subject to this law, and its provisions become more exacting in proportion to the number of years which have elapsed before his error is corrected. The following table gives in the first column the patient's age, in the second, the mean accommodation and in the third, the amount of this available in percentages:

Patient's Age in Years	*Mean Accommodative Power in Diopters*	*Amount Available in Percentages*
10	13.4	75
15	12.3	55
20	11.1	40
25	9.9	35
30	8.7	30
35	7.3	25

From this it will be seen that between the ages of 20 and 25 he will need accommodative help and should he remain unglassed until his 35th year, he will need his full presbyopic correction in bifocals.

This table gives a workable basis, but is subject to modifications governed by the individual amplitude of accommodation. It is a nice question to decide as to what shall be the lenticular prescription for near work and whether the full cycloplegic correction is suitable for all purposes.

A myope of 2.50 diopters or more has no need for accommodative action and of necessity an unexercised ciliary muscle must decline in function. The amount of impairment determines what shall be done with lenticular assistance and the treatment should be that proper to subnormal accommodation.

It is necessary in all cases to determine the amplitude of accommodation—measured with the distance correction in place, and if found markedly below the mean for the patient's age weaker glasses must be given for near work. For example, at 20 years of age, the mean accommodate power is 11.00 diopters with only forty per cent available. This is not enough reserve for continuous near work. The simplest plan in such a case is to give the needed addition in cemented bifocals for temporary use. It will be found usually in young adults that the accommodative power will increase under constant use of the distance correction and later the pasters may be removed, leaving the whole lenses for all purposes. If the available reserve runs around sixty per cent, full correction may be tentatively prescribed with these instructions, "Let your near work be done in good light, with good print, held as *far away* as is consistent with sharp definition." If, after a reasonable period of trial discomfort persists, the above plan of bifocals will have to be adopted.

CHAPTER XIV

ASTIGMIA

In my experience this may be assumed as a constant associate to other refractive states, or existing alone. Twice, and twice only in my professional work, have I met with the emmetropic eye, and only five times eyes with no apparent astigmia. Three of these were myopes of unequal refraction, and two were hyperopes of equal error.

The correction by a 0.12 diopter cylinder has never seemed necessary to me, but this fractional difference should be reckoned with up to errors of 2.00 diopters. By this is meant that 0.37, 0.62 etc. should be chosen over 0.25 or 0.50, if these small additions are acceptable.

The rule of the strongest plus or the weakest minus applies alike to sphere and cylinder. The accommodation can take care of small mistakes in the spheres without resultant harm, but not so with the cylinders. Absolute accuracy both in power and axis is a sine qua non to ocular comfort or relief from eye strain, manifest perhaps only in reflex disturbances.

There are cases where objective tests by retinoscopy and ophthalmometry indicate a higher error than will be subjectively accepted. In these instances, if the disparity be great, the patient must be warned that an early retesting may be necessary; if the difference be small, say from 0.25 to 0.50 diopter my own practice has been to give the full correction, tell the patients that distance vision will be blurred, and have them report after two weeks constant wearing of the glasses.

If the ciliary muscle has established so great a habit-spasm that it will not relax in that time, it is a simple matter to resurface the lens and take off some of the power. Also is it true that this habit spasm may alter slightly the cylinder axis; if so, resurfacing can rectify this also.

There are so many factors entering into power and axis of the cycloplegic correction that their final disposal can not be considered here. At this test, under ciliary inaction, all that can be determined is the *apparent monocular* acceptation of the lens which gives the best vision. Why this may differ greatly from the post-cycloplegic correction will be taken up later. At this stage, mathematical exactitude is not the goal. While from the data, objectively determined, of the corneal curves, the cylindric error may be approximately estimated, it is the axial error which becomes of paramount importance.

Often it is, that anisometropia is the main disturbing cause of painful vision; *e.g.* with equal visual acuity, one eye, let us say, has a hyperopia of 1.50 diopter and the other none. If this is in the dominant eye, the right in a right-handed person, or vice versa, it is a trouble-breeder of greater or at least of equal importance to the astigmic error. To secure sharp binocular fusion, this eye must accommodate more than its fellow. This unequal effort can not be long maintained in comfort.

When we come to the final correction, the astigmic errors are first monocularly scrutinized and the spheric additions are governed binocularly by what was found under cycloplegia; *e.g.* right eye plus 1.50 combined with plus 1.00 axis 90; left eye plus 1 diopter cylinder axis 90. If these cylinders checked up are found correct, and we determine upon a plus 0.50 deduction, with both eyes open the right eye becomes plus 1.00 combined with plus 1.00; and the left minus 0.50 combined with plus 1.00 at vertical axes.

The acceptable correction of anisometropia depends upon the degree and kind. I have already mentioned that a hyperopic difference of 5 diopters where the source was from curvature and not axial discrepancies, permitted of greater differences in lens strength than would be possible were the errors both axial. The classic allowance of only 1.50 diopters between the two eyes is based not on refractive differences but on prismatic deviations.

Theoretically a lens of any power, placed at the anterior focal plane, should give, in size, corresponding retinal images; and no matter what the differences may be between the two eyes, should be wearable if only the central zone of the lenses is called into use. Immediately the plane of regard passes from this zone, there enters the factor of prismatic deviation incident to the visual line falling eccentric to the optic axis of the lens.

Prentice has formulated a rule whereby the prism power may be computed. This is: "For each diopter of refractive power, a decentration of one centimeter induces one centrad of prism power." *e.g.* plus 10.00 diopter sphere decentered up 2.5 millimetres (one-fourth centimetre) equals four prism centrads base up.

Plus powers may be regarded as prisms with bases coincident, minus powers with apices in touch; therefore, the prism bases, in plus powers, move in the same direction as the decentration, and in minus powers opposite. Unfinished blanks are now made 52 millimetres in diameter, so that several millimetres of decentration is possible. In high powers this gives us ample leeway, but if on a one diopter lens one prism centrad is required, it cannot be obtained by decentration, but must be ground *de novo* on a plane blank, or at least on one unfinished on one surface. The rule is: Deduct from 52, the vertical diameter desired for the finished lens; half of the remainder is the amount of the decentration possible; *e.g.* say the finished lens is to be 38 millimetres in vertical diameter, 52 minus 38 equals 14, divided by two, equals seven. This then is all the space available, and on a 1.00 diopter lens the effect is less than one prism centrad. Of course I am speaking now only of cases that require prismatic correction in the distance.

In anisometropes where this is needed in the near, as prismatic bifocals (plano- or sphero-prisms), another rule comes into play. Lenses properly placed before the face should have their optical and geometrical centers coincident, and these vertically aligned at the mid-pupillary points, but horizontally should be placed two millimetres higher. Therefore, when we wish to find the prismatic displacement in a lens of given size, we first find how far from the optical center the line of regard will fall under working conditions for near. The rule is: "Subtract from the vertical semi-diameter of the lens two millimetres and divide number so obtained by two." For example, take a lens 38 millimetres in vertical diameter; 38 divided by two equals 19, minus two equals 17, divided by two equals 8.50. Thus the line of vision falls 8.50 millimetres below the optical center.

To find the prismatic effect so induced, we multiply .85 by the dioptric power of the lens. If this should be 4.00 diopters, then four times .85 equals 3.40 prism diopters.

Now the reason why only 1.50 difference was allowable is that while an eye will stand, with reasonable impunity, quite marked disparity between the common relationships of adduction and abduction, it will not do so when supra and infraduction are called into play. With a 38 millimetre lens of 1.50 diopter the displacement is equal to a prism of 1.275. This is about the limit possible with comfort.

What are you going to do when the anisometropia would induce errors far in excess of this—admit defeat, and let the eye go uncorrected, or what? If the high error is in the dominant eye, failure to correct spells disaster. Here is a concrete example taken from my case records. Young adult, righthanded, with ample accommodation, gets normal vision in the right eye with a plus 4.00 diopter cylinder axis one hundred eighty; left eye, no error. Now it is a fact, without adequate explanation, that use of the dominant eye will be persistent even though great visual disparity exists between this and its fellow, and hence binocular vision becomes uncomfortable. The plus 4.00 cylinder equalized vision, but its use was impossible. The size of the lens was thirty-eight millimetres, in vertical diameter. At his working point, 8.50 millimetres below the center, he got a prismatic displacement of 3.40 prism diopter base up. He was given his cylindric correction in his right eye, and over the left a plano lens with a prism paster base up. Result, comfort and a restoration of visual function to the eye upon which he must depend.

Had there been a need for cosmetic value, the same lenticular result could have been obtained by using an Ultex plano-prism addition, with the base down over the right eye. With marked differences in the power of the two lenses then the algebraic difference must be determined along the lines of regard both vertically and horizontally.

A myope of 2.00 diopters in one eye and 6.00 diopters in the other may be graphically expressed thus: right eye a cross opposite both arms of which is marked a minus 2.00 power, left eye a cross opposite both arms of which is marked a minus 6.00 power. Subtracting gives a difference of 4.00 diopters of myopia in both meridia. At the reading distance the lines fall only about 3 millimetres to the inside of the optic centers, and the total prismatic effect induced is only 2.4 prism diopters base in (0.6 in one eye, 1.8 in the other). This minor stress imposed on the external recti is not appreciable, but in looking down the patient is in the same fix as is the one with the plus 4.00 cylinder, only now, the base position of the prism is reversed, down instead of up. Without a prism addition to the lower half of one lens, such glasses are unwearable. So far as looks are concerned, it is much better to make this addition as an invisible bifocal. It can't be done with a Kryptok, and while an Ultex prism can be ground with the base up, what it looks like cannot be expressed in phrases fit to print. The best plan is to put a three degree prism base down over the weaker lens, and to lightly outline with a diamond mark a corresponding area on the other glass.

Dioptral differences in the vertical plane are of more importance than those in the horizontal, but cases occur in which these are not negligible.

With the sphero-cylinders it is easier to reckon differences by the graphic method. Let us say we have: right eye plus 2.00 combined with plus 4.00 axis ninety; left eye plus 2.00 combined with 4.00 axis one hundred eighty. This is an extreme instance, but serves as a striking illustration. Graphically, right eye may be expressed as a cross the vertical arm of which carries a power of plus 2.00 the horizontal a power of plus 6.00, left eye as a cross the vertical arm of which carries a power of plus 6.00, the horizontal a plus 2.00. Thus the power in the vertical meridian of the right eye is 2.00 diopters while it is 6.00 diopters in the left.

As a basis for calculating prismatic displacement, we must subtract powers of like sign and add powers of unlike sign before each eye, having thus a difference between the two in inequality of 4.00 diopters in both the vertical and horizontal meridia. There is presented the same problem as in the first instance, but now the lateral muscles come into play. Again, as with the anisometropic myope, this is negligible, for the minor stress now falls on the internal recti which have a much higher reserve of power than have the externi.

A cylinder induces no prismatic error when viewed along its axis; only at right angles to this is any displacement produced. But when placed before the eye at an oblique axis, it exerts power in both directions. A 4.00 diopter cylinder

HORIZONTAL AND VERTICAL
PRISMATIC EFFECTS
OF
OBLIQUE AXIS CYLINDERS

CHOSEN DEPTH OF VISUAL POINTS

Prismatic Base Dir'n (Axis 0° to 90°)	0 to 90° Axis	5 mm.		6 mm.		7 mm.		8 mm.		9 mm.		10 mm.		90 to 180° Axis	Prismatic Base Dir'n (Axis 90° to 180°)
		Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.		
	0°	.00	.50	.00	.60	.00	.70	.00	.80	.00	.90	.00	1.00	180°	
	5	.04	.49	.05	.59	.06	.69	.07	.79	.08	.89	.09	.99	175	
	10	.09	.48	.10	.58	.12	.68	.14	.78	.15	.87	.17	.97	170	
For Plus Cyl. Rt. Eye, up & out Lft. Eye, up & in	15	.13	.47	.15	.56	.18	.65	.20	.75	.23	.84	.25	.93	165	For Plus Cyl. Rt. Eye, up & in Lft. Eye, up & out
	20	.16	.44	.19	.53	.22	.62	.26	.71	.29	.79	.32	.88	160	
	25	.19	.41	.23	.49	.27	.57	.31	.66	.34	.74	.38	.82	166	
	30	.22	.38	.26	.45	.30	.53	.35	.60	.39	.68	.43	.75	150	
	35	.24	.34	.28	.40	.33	.47	.38	.54	.42	.60	.47	.67	145	
	40	.25	.29	.30	.35	.35	.41	.39	.47	.44	.53	.49	.59	140	
	45	.25	.25	.30	.30	.35	.35	.40	.40	.45	.45	.50	.50	135	
	50	.25	.21	.30	.25	.35	.29	.39	.33	.44	.37	.49	.41	130	
	55	.24	.16	.28	.20	.33	.23	.38	.26	.42	.30	.47	.33	125	
For Minus Cyl. Rt. Eye, dn. & in Lft. Eye, dn. & out	60	.22	.13	.26	.15	.30	.18	.35	.20	.39	.23	.43	.25	120	For Minus Cyl. Rt. Eye, dn. & out Lft. Eye, dn. & in
	65	.19	.09	.23	.11	.27	.13	.31	.14	.34	.16	.38	.18	115	
	70	.16	.06	.19	.07	.22	.08	.26	.09	.29	.11	.32	.12	110	
	75	.13	.03	.15	.04	.18	.05	.20	.05	.23	.06	.25	.07	105	
	80	.09	.01	.10	.02	.12	.02	.14	.02	.15	.03	.17	.03	100	
	85	.04	.00	.05	.00	.06	.01	.07	.01	.08	.01	.09	.01	95	
	90	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	90	

NOTE—Multiply the dioptral power of the cyl. by the number found above. (This number is the excentroprismatic power of a 1D Cyl. at various axes and depths.)

at forty-five or one hundred thirty-five is equivalent in effect to a 2.00 prism diopter both vertically and horizontally disposed. When cylinders of more than fractional power are made part of the correction, their effects in both directions complicate the problem.

Tables giving these powers at all axes from ninety-five to one hundred eighty, and for plus and minus cylinders, have been compiled, and to this the reader is referred on previous page.

Few patients have a total fusional power of more than 2.5 prism diopter vertically disposed, and many hardly more than 1.5. It becomes imperative, therefore, to add to an exact refractional correction a meticulous estimate of a comfortable muscular adjustment.

CHAPTER XV

REFRACTION AFTER OPERATION FOR CATARACT

An aphakic eye with clear media and a normal fundus presents the simplest of all refractive problems, but the selection of the corrective lens is another matter altogether. Even if you have worked out your problem successfully, the choice can not be left to the optician, for he will usually take the path of least resistance and make up for your patient an unwearable lens, unless you specify in exact terms *how* this lens shall be ground.

The first step in the refraction is the determination of the corneal flexure by the ophthalmometer. The vertical meridian has almost always a longer radius than the horizontal, so the disposition of the cylinder axis is "against the rule."

To correct the high hyperopia resulting from the removal of the lens, there must be superposed upon the cylinder plus spheric lenses, the power of these depending upon the preoperative refraction. In proportion as these lenses are stronger, so do the cylinder values become less and the necessary departure of the correcting lens from the anterior focal point make them smaller still. *e.g.* if the eye had been emmetropic, and the ophthalmometer showed 3.00 diopters of astigmia and a plus 10.00 diopter sphere were the spheric addition required, it would work out as a plus 2.00 diopter cylinder instead of plus 3.00.

For these reasons it is a safe working rule to deduct one-third from the power of the cylinder found by the ophthalmometer, and starting with this at the axis indicated by the instrument, superpose spheres of differing powers until the maximal vision is obtained. The refraction, however, is now only roughed out.

The next step is to try out minor shifts in the cylinder axis. An aphakic eye can differentiate between positions one degree apart. Having satisfied ourselves as to the best location, bring the cross-cylinder into play, using the 0.50 crossed on a 0.50. One turn will tell you whether the tentative cylindric power is too weak or too strong. If a change is indicated, make it, but before going further try out weak plus 0.50 or minus 0.50 spheres, over the combination in the trial frame. Make whatever change may seem required.

For the final test repeat the above procedures, but this time using the crossed 0.25's and minus or plus 0.25 spheres.

While the estimation of the refraction is not difficult, the final prescription becomes an intricate problem, and the grinding of this lens an even greater one. Two prime factors are involved in the prescription. One is the reduction to effective power of our trial case correction; the other the compensation for differences incident to change in power between the testing and the wearing position of the glasses. If the newer trial cases are used where the lenses are all of the same thickness and all computed in effective power, it is not necessary for the refractionist to concern himself with the first factor, but he must if he has been using the biconvex spheres and the plano-convex cylinders of the old type of trial lenses. If he has, it is impossible that these can be so placed in the trial frame as to exert such collective power as would result were they ground into a single lens, and this placed fourteen millimetres from the apex of the corneal dome.

To determine the effective power a simple rule may be applied. Let diopter prime, equal power of anterior surface, diopter second, equal power of posterior surface, *d.* equal thickness of lens in metres, *n.* equal index of refraction of the glass. The formula is (diopter prime plus diopter second) minus (d. over n. multiplied by diopter prime, multiplied by diopter second).

If our original finding was a plus ten combined with a plus 2.00 cylinder at one hundred eighty, and if the thickness is .004 metres and the index 1.523 plus, it works out for the horizontal meridian 9.34 diopters plus and for the vertical 11.15 plus. It is understood that the powers in both meridia must be calculated. Taking the nearest lenticular values, our original plus 10.00 combined with plus 2.00 becomes plus 9.25 combined with a plus 1.75.

Now comes in the second factor. How far away from the eye were these lenses when the test was being made, and what will the powers become when the finished glasses are placed where they should be, *viz.,* at the anterior focal point?

Measured—the first position was nineteen millimetres; the final must be fourteen. The rule for this is simple also. "Square the power (each meridian taken separately). Multiply this by the difference in millimetres between the two positions, and divide the sum by one thousand. Add the fractions so obtained to find what shall be the powers when the lens (given above) shall be brought nearer to the eye. We now have in nearest lenticular values a plus 9.75 combined with plus 2.00, approximately, as the final prescription to be sent to the grinder.

Now what directions are we to give him? Shall we let him work his own sweet will and crab an act which we have worked up to perfection? Or shall we so stipulate what he is to do that the conditions of both refractional and optical exactitude shall be observed?

Surfaces of least refraction should go nearer the eye; so in the following, the first power always indicates exterior surface. This lens may be made up as: plus 9.75 combined with plus 2.00; or, sphero-toric (plus 6.00 combined with plus 8.00) combined with plus 3.75; or, two cylinders, one of 11.75, the other of 9.75 crossed at right angles; or, a plus sphere on a minus cylinder. But if we do the latter we must revert to our ophthalmometer findings and make it plus 12.75 combined with minus 3.00 diopter cylinder. Another choice is to use a minus toric on the back and a stronger plus sphere in front, and if so shall the minus toric be on a three, six, or nine base curve?

Here is an embarrassment of riches. Our choice runs over a larger range than Portia's, but like hers there is only one right box. To go by chance is like opening Pandora's, and lose all the gain we have so far obtained. Here enters the economic factor; a perfect optical correction for the aphakic eye is an expensive thing. The choice, from those of lesser cost, is the second of the above, a sphero-toric on a plus 6.00 base curve. Incidentally it may be here interpolated that a cataract lens should be decentered down three millimetres to obviate the slanting of the floor which otherwise it will appear to create, and which so disturbs the patient's spacial relationships. The crossed cylinders and the minus cylinders on the stronger plus sphere need not be considered. The ordinary sphero-cylinder is better than either of these, but it does not admit of clear peripheral vision through it and only a very limited central zone of this lens is utilizable.

This phase of the topic will be further elaborated under the caption "The Ophthalmic Lens." Here it is sufficient to say that a lens can be ground to eliminate practically all spheric and cylindric aberration up to sixty degrees from its center.

In the aphakic eye the nodal point is situate at the center of curvature of the cornea. The imposition of a strong plus lens brings the nodal point forward, and larger retinal images result. In fitting the aphakic eye all we need to know is what plus correction gives the best vision under testing conditions. The lens we shall prescribe is a matter of calculation involving the factors already mentioned.

We require additional apparatus to do this prescribing intelligently. In the first place, the inter-pupillary distance must be accurately measured, and chiefest of all, the exact distance from the apex of the corneal dome to the back surface of the lens must be calculated from the anterior focal point (fourteen millimetres). To make these lenses is an optical triumph. To correct peripheral aberration so that vision may not be restricted to the central zone, only one surface can be spherical or sphero-toric; the other (the inner curve) must be ground on a paraboloid, and for every power of correction, both spheric and cylindric, a separate computation must be made. No lens over seven diopters can be made point-focal with spheric curves, and with very high plus powers, it is a matter of the nicest calculation to make them periscopic, using this term in its exact sense. If the expense is prohibitive—the cost is about forty dollars a lens wholesale—a close approximation to periscopy may be obtained by grinding a minus toric on a three base posteriorly and a stronger spheric curve outside.

CHAPTER XVI

THE POST CYCLOPLEGIC CORRECTION

The cycloplegic correction may be determined by the observance of a few simple rules. The post-cycloplegic calls for a high critical faculty, a nice judgment, an accurate knowledge of the factors which may enter to create differences between these two tests, and a ripened wisdom to correlate and harmonize discrepancies, should such occur. More than this, the cycloplegic is a monocular affair; the post-cycloplegic must reckon with the many problems of binocular single vision. The outstanding data of the cycloplegic test are the determination of how great is the total axial and the manifest astigmic refraction; the post-cycloplegic mostly concerns the corneal errors.

Of course, there are only two essentials in the astigmic correction—power of cylinder and its axis. The first is the lesser of our two difficulties. Under normal conditions we use only an area of the cornea, about four millimetres in diameter. This usually has regular spheric or sphero-cylindric curves, but outside of this, as we approach the periphery, the curve becomes progressively less until the corneal flexure may merge into flatness.

It is evident that an attempt to induce sharp foci with a widely dilated pupil is an impossibility, and efforts directed to this end are handicapped by these optical aberrations. Thus it may happen that a sphero-cylindric correction may have too much or too little power of either sphere or cylinder or both. These variations, however, are fractional, but must be borne in mind, as they are important in the estimation of cylindric *power.*

Imperative is the matter of the axis. It must be exact. Approximation does not fulfill the requirements of scientific refraction work. Not only does the cycloplegic interfere with focal exactitude, but *occasionally* it plays havoc with the proper axis determination. It has been experimentally proven that once in a while the drug soaks under the corneal epithelium and raises this into a little mound. If this elevation occurs near the true cylindric axis, this is displaced toward the foot of the mound; so it follows that the cycloplegic and post-cycloplegic axes may be found at variance by so much as from ten to twenty degrees. In my own experience I once found a 3.50 cylinder move over from seventy-five to fifty-five. Usually fifteen degrees at the most covers this deviation. Incidentally it is not the homatropine, but the cocaine ingredient that causes this trouble, so if solutions are to be used, not more than one-half per cent. of this latter drug should be incorporated.

Next in order is a cyclotropia or a cyclophoria which may intrude to modify our findings. Remember this is now in the stage of the monocular tests. If there be an oblique astigmia of such amount as to render appreciable the lack of fusion upon corresponding retinal points, then to obtain binocular single vision, the superior or inferior oblique muscle must receive an extra innervation to overcome this difficulty. Now with the other eye occluded, the one under test will fall into the position of repose and the cylinder axis assume its true position. In other words, what might have tested out at one hundred five, under ciliary inaction now shows up at ninety. This phase of the subject will be taken up under binocular single vision and the muscular imbalances.

Thus we have a personal equation with three inconstant factors. Consulting our cycloplegic findings we first superpose the cylinder so found. If the cylinder be weak and the sphere strong, it may be necessary to use a partial spheric addition, because in any event we must first obtain good vision before we can determine with any certainty power and axis in the cylinder. Particularly is this true with minus powers or with high plus and failing accommodation.

Our first concern is cylindric power. Here the cross-cylinder (0.12 combined with 0.12) comes into play. Powers of like sign and then of unlike sign parallel to the axis of the tentative cylinder are tried out. With like signs the question is (the patient's attention being centered on a single letter): "Does this bring out that letter more distinctly?" or, reversing the axis, "Does this?"

Time must be given for apperception with the first addition so that, with the second change, now made rapidly, an easy differentiation may be made, or none be found possible. If the latter occurs, we may assume that the power of the cylinder *at this axis* needs no change. With strong cylinders, say about 2.00 diopters all we need do is to test greater or less legibility under a tilting of the trial frame up or down or, what is its equivalent, have the patient tilt his head toward one or the other shoulder. Incidentally it may be here interpolated that for patients who habitually carry the head tilted toward one side, mistakes in axes will occur unless this faulty position be first rectified and insistently maintained. The head being carried in this fashion may be due to an oblique astigmia, but usually to a vertical muscle imbalance.

If we find vision is improved by a change in axis, then power must be retested with the same weak cross cylinder. Often has been seen, with a five degree shift of axis and a power addition or subtraction of 0.25 diopter, a high accrual in visual acuity. With weak cylindric lenses axes are with more difficulty ascertained and in fact with these—say of from 0.25 to 0.50 in power—a displacement even of ten degrees either way from exactitude gives about the same vision, but not the same comfort.

How are we to discriminate when the patient can not? Say we have one hundred per cent. vision with the approximate correction in place. This is too little anyway, but we will let this pass for the moment. Taking off the cylinder, we change successively into higher powers (at the same axis) until vision is cut down to eighty per cent. with probably most of the confusion letters illegible. Fixing upon one letter of which the patient is sure, we test definition by alternately shifting axis from right to left until the best position is found, and now the confusion letters must come out or the test be repeated on the most difficult of these. Say they all come out. Now we superpose cylindric powers of unlike sign until again one hundred per cent. is visible. When this is obtained, we go through the same procedure on the one hundred fifty per cent. line. This is the proper method with plus on plus combinations; with minus on minus, or with minus cylinders alone, the cylindric increase must be accompanied by a spheric decrease; or where only minus cylinders were accepted, by a plus spheric addition of equal value to the cylindric increase. For example, with a minus cylinder of 0.50 diopter at one hundred eighty, the tests are made with a plus 0.50 diopter at ninety. With every improvement found either from a change in axis or power, we proceed to juggle with weak plus or minus spheres superposed until further improvement is no longer possible.

Mind you, all this elaboration has to do only with cylinder effects; the spheric additions come in later. The other eye is gone over with identical methods, and now once more we refer to our cycloplegic findings.

There is a normal ciliary tonicity which may not be disregarded with impunity. What spheric deductions, therefore, shall we make for our final prescription? This tonicity varies with the individual, and often a patient with less than 1.00 diopter of hyperopic astigmia will prefer a minus cylinder, finding more comfortable an induced hyperopia all around than the induction of emmetropia.

I may say here at once that for myopic errors no deduction should be made. At twenty feet a myope is undercorrected by 0.16 diopter, and this matters not unless the lenses are to be used exclusively for outdoor work. In any event the lenses should never have an added power over 0.25 diopter.

In mixed astigmia the same rule holds good. Even a proportionately small minus spheric finding does not invalidate this precept; *e.g.* minus 0.50 diopter sphere combined with plus 2.00 diopter cylinder should be ordered as found. Where both powers are very weak, say a minus 0.25 diopter combined with plus 0.50 diopter cylinder, the patient will more gratefully accept a minus 0.50 diopter cylinder.

With strong plus sphero-cylindric combinations, there enter the questions of the phorias, the age of the patient, the amplitude of accommodation, and the purpose for which the glasses are to be used. A clerical worker or sewing machine operator needs a stronger plus lens than does a salesman who only occasionally uses his eyes for close work. A hyperope with esophoria should have as near his full correction as will be tolerable. With exophoria a large subtraction *may* be indicated, but consideration must be given to his point of near convergence and his reserve of accommodation, and if his pupillary distance be over sixty-five millimetres it may be necessary to add prisms base in. A young hyperope of say six to seven diopters of error may require a subtraction of from 1.00 to 1.50 diopters, but this implies that his high error has induced more or less ciliary spasm. My own rule has been to give such lenses as will permit of sharp vision on the penultimate line secured at the cycloplegic test; for instance if he then got one hundred fifty per cent., he is left with one hundred per cent.; if the latter, with eighty per cent. The patient is told that while vision for near will be sharp and clear, that for distance will be blurred. He is also told that only through relaxation of the cramp which caused his eyestrain can he get comfort, and that leaving the glasses off even for a single day will cause a tendency for the spasm to return. Except in high astigmic or myopic errors, he is told that his glasses are not given to improve his sight, but that in a short period, say two weeks of constant use, he will see *as well* with them as without them. He is warned that a misplaced or dirty lens will cause a return of the eye strain, and that the lenses must be kept clean and be worn in proper position.

When the astigmic error is satisfactorily corrected the cycloplegic error is again referred to. Now with both eyes glassed with cylinders, an equal tentative spheric subtraction is made and the vision again taken. Let us say the spheric error was plus 1.00 and plus 1.50 respectively; if from 2.00 to 2.50, the subtraction rarely needs to be more than 0.50 diopter. Taking the first example, and putting on a plus 0.50 and a plus 1.00 addition to the cylinders, we may now find that instead of one hundred fifty per cent. vision, it falls to eighty per cent. Weak minus spheres (0.25 diopter) superposed simultaneously over both corrections do not improve. In this event we are probably dealing with a vertical muscular imbalance.

Vision is usually better binocularly than it is monocularly. If it does not so test out, most certainly must there be a vertical muscle imbalance; or if the correction contains a strong oblique cylinder, its axis is not correctly placed for binocular functioning and on further testing a cyclophoria or cyclotropia will be unmasked. I know of no more perplexing problem, to insure comfortable binocular vision, than is involved in this condition.

Here the data given by the ophthalmometer are invaluable. If the external canthi had been in line with the guiding marks, the axis as found by the instrument should largely determine the cylinder position in binocular vision.

We may also get a clue by inducing monocular diplopia with the double prism over one eye, bases horizontal, and the test object a horizontal line at the reading distance. Now appear three lines, the central one belonging to the other eye. If this line departs from parallelism with the other two, it indicates a torsion of the vertical corneal meridian either nasalward or temporalward. If the center line tips *up* nasalward, it indicates an extorsion (plus cyclophoria); if up temporalward, an intorsion (minus cyclophoria). This test is applied first to one eye, then to the other.

Here enters in the matter of physiological minus cyclophoria at the reading distance, and the law of corresponding retinal points. With convergence and infraduction both called into action, the vertical meridia of both corneae converge. This makes objects appear larger at the top than at the bottom. It does not matter so far as print is concerned, for type is cast smaller at top. Note the e's, the a's and the s's on any printed page. But what does matter is the application of the law of corresponding retinal points. Let us cite as example an *uncorrected* pair of astigmic eyes say of plus 2.00 diopter cylinder, with axis at one hundred five in the right; while the other is astigmic with axis ninety. It is impossible that these images, falling on dissimilar retinal points, can fuse unless the right superior oblique intorts nasalward, the vertical meridian of the cornea inducing a minus cyclotropia.

The practical point in refraction is that the instant the exact correction is applied, the need for this false declination disappears; but the habit, perhaps of years, does not. There remains a residual hypertonicity in this muscle which will tend to throw the axis of correcting cylinder nasalward from the position which was found under monocular testing.

Vision, as has been said before, is a cerebral faculty and the uncorrected astigmia produces a distorsion optically which is compensated for cerebrally, and when we throw this out of use by lenses there occurs a reverse distorsion which may render even an accurate correction unwearable. How are we to overcome this difficulty? I am referring now to an oblique astigmia. Incidentally it may be interpolated that with axes horizontal or vertical there is no distorsion, and the full cylindric correction is usually acceptable from the first. In oblique astigmia with divergent axes, the problem is simpler than it is with axes convergent, for the superior oblique is of less power than the inferior and will sooner relax. With the astigmic error small, or when combined with a relatively high axial error, little heed need be given to the metamorphopsia; but with conditions reversed this becomes a dominant factor in the patient's comfort.

Let us first take up oblique astigmia of high degree and with divergent axes. Having found by the ophthalmometer the power and axis with monocular vision, we place the cylinder at this axis and note in binocular vision what is the distorsion induced. Now of course, theoretically, we have thrown the image upon corresponding retinal points, and there should be no actual distorsion. But unfortunately there is, owing to psychic fusional and essential innervational disturbances. For the sake of simplicity it is assumed that the other eye has no astigmia, or that if it have, the axis is vertical. The superior oblique does not let go at once, and the cylinder axis is thereby shifted nasalward. Test this out, and see if a five degree change will materially rectify the metamorphopsia and clarify the distance vision. If it does not, there is no alternative other than to give a weaker cylinder to make the distorsion bearable. The same applies even to a greater degree with astigmia with converging axes. The stronger inferior oblique will less easily give up its bad habit.

If weaker cylinders are forced upon us, they must be gradually increased in strength, as the mental concept adjusts itself to the changed conditions. If we must resort to weaker cylinders, we ignore a possible hypertonicity of the obliques and set these cylinders at the axis previously determined. With diverging axes the strength may tentatively begin with one-half; with converging, one-third.

Here enters another factor to complicate the optical problem: The question of expense. So any method which will minimize this is worthy of consideration. The order to the optician will be to select spectacle frames with shanks thrown under, so that round lenses as large as possible may be utilized, and mark these with a scratch coincident with a mark on the inner surface of the rim. If the case is one where we are beginning with weaker cylinders, have these lenses two millimetres thick at the bevel. Now when we make the change from one-third to two-thirds, and on to full power, the lenses may be resurfaced at a much lesser cost than making new ones; and when the final correction is reached they may be re-sized and properly re-mounted as ovals. There are, however, certain objections to this plan, one being that from the two grindings the edges of the lenses may become over-polished and an unwanted spheric aberration induced. Perhaps the better plan would be to make up the prescription in flat cylinders or sphero-cylinders, in the frame to be ultimately used, and when permanence of power is finally obtained, re-order in toric form.

Under ordinary conditions, cylindric lenses should never be given in round frames, as they are apt to loosen and the axes become misplaced. If it is a case where we are simply to shift the axis from its tentative to its final permanent position, then the thickness at the bevel should be that usually employed. With axes converging we may set the cylinders at the axis indicated, and test out in the distance (two Maddox rods, one over each eye at right angles) to see if there be left any residual cyclotropia. If so, the axis may be set nearer the ninetieth meridian, moving this temporalward, and noting the departure in degrees, so that while the desired axis is marked on the lens and the frame, they are no longer coincident. This is understood to be a temporary expedient, and also it is to be noted that the reverse applies to myopic astigmia, for now the axes converge downward and the shift is toward the one hundred eightieth meridian. This is to compensate for over-action of the obliques, but as will be shown later, does not apply to strong cylinders when we wish to minimize the metamorphopsia.

Of all vicious and perplexing conditions, nothing surpasses an oblique astigmia in which the torsional imbalance is grafted onto an essential cyclophoria. A cyclotropia disappears the instant that the oblique astigmia is corrected, and even before this is done it gives no objective evidence of its presence because the vertical and horizontal meridia of the cornea are made by the obliques to cross at right angles.

To determine a cyclophoria one may place vertically a Maddox rod before each eye, and then induce vertical diplopia with a six or eight prism base up. If before the right eye, the patient will now see two lines, the lower one belonging to the right eye, the higher to the left. If the upper line appears to be horizontal, but the lower nearer the nasal than the temporal side, there is a plus cyclophoria (the vertical corneal meridian inclining nasalward). If the lower line approaches the temporal end, there is minus cyclophoria (the vertical corneal meridian inclining temporalward). The left eye is tested in the same way. The laws of projection make these phenomena readily understandable. An intorted eye makes a vertical line incline outward, and lengthens a horizontal one. An eye extorted induces the opposite effects.

To test cyclophoria at the reading distance, instead of using the Maddox rods we now employ the double prism (two prisms bases co-incident) ground upon a single plano lens, placed before the eye with the base line horizontal, the test object being a black horizontal line marked upon a white card. Let the patient hold this card at the reading place and at the reading distance. Now lower the frame holding the double prism until the base line just bisects the pupil. There will now appear three lines upon the card, the middle one belonging to the uncovered eye. Any departure from parallelism indicates a cyclophoria. The test is repeated with the double prism over the other eye. The interpretation of the phenomena observed is the same as in the distance tests. The middle line inclining upward nasalward indicates plus cyclophoria; inclining in like fashion temporalward, indicates minus cyclophoria.

It is to be understood that these tests are made with the lenses correcting the refraction for near in place, and that extreme care is to be used in adjusting the Maddox rods and the double prism exactly at right angles to the sagittal plane of the head.

While parts of the foregoing might, and properly do, apply to the ocular muscle imbalances, they are particularly pertinent to binocular single vision and its comfortable maintenance.

If a cyclophoria is detected associate with a corrected oblique astigmia, what is to be done about it? This chapter has nothing to do with the surgical correction of this condition; it deals only with the optical. Those who wish to go deeper into this matter are referred to George T. Stevens' book on the "Motor Apparatus of the Eyes." (F. A. Davis & Co.)

Of the value of any cycloduction exercises I have my doubts. To employ these, one must convert the spot light into superposed horizontal lines by means of two Maddox rods vertically disposed, one over each eye. Plus cyclophoria is an over-action of the inferior oblique or an under-action of the superior; a minus cyclophoria is the reverse of this. To exercise the superior obliques the Maddox rod is rotated nasalward, until the vertical line breaks into two, crossing each other obliquely. When this occurs, the rod is again returned to its vertical position. This technique is repeatedly carried out. For minus cyclophoria (which is very rare) the technique is reversed. Unfortunately the linear images thus induced so diminish the impulse to binocular fusion, that even a slight alteration of either rod from its position, either side of verticality, induces an oblique crossing of the lines. There is nothing to prompt fusion, and the eye remains in its position of repose.

Two questions come up incident to this phase of the subject. The first is: "Does an essential cyclophoria exist in the absence of oblique astigmia?" The second is: "If so, is it anatomic or innervational?" No definite answer can be given to either question. All that can be brought in would be a Scotch verdict "Not proven." What concerns us here is how shall we meet torsional imbalance optically?

Occasionally one meets with cases in which the cylinder axes for distance and those for the reading point are at veriance. If a compromise cannot be reached, there remains only the giving of two different pairs of glasses. Already have been given the tests for the cyclophorias. If, with the reading glasses in place, the middle line is not parallel, make it so by shifting the axis of the cylinder. Removing the double prism, we test the reaching ability on the fine type. If not clear, move the cylinder back a few degrees until it is, and re-test for parallelism with the double prism. When the axis is found in which both conditions are satisfied, this is the axis which should be ordered for the reading distance. If added plus spheres were needed in the near, remove these and re-test for torsional imbalances in the distance. If a marked discrepancy becomes manifest in presbyopics, either two pairs of glasses or perfection bifocals must be given. This, or its alternative—split bifocals—will be given attention under "Bifocals." Incidently the cyclophoria test in the near will reveal other than torsional imbalances, should such exist. If the middle line, when made parallel, is nearer the upper of the other two lines, it means that eye is relatively too low as compared with its fellow; if nearer the bottom line, too high. If the center line projects to the opposite side beyond the other two, it indicates deficient convergence; if toward the same side, convergence excess.

If we wish to spare the patient the expense of frequent changes of his glasses, we adopt the procedures advocated by Dr. Savage of Nashville. With the full cylindric correction in place (where there is a cyclophoria) with the meridia either diverging or converging above, the axes of plus cylinders should be displaced toward the centers of the quadrants in which they are found, and the axes of minus cylinders away from the centers in which they are found. This is not to correct the cyclophoria, but to render bearable the induced metamorphopsia. As this diminishes, the axes should be shifted every few days a few degrees near to the axes found under monocular testing. To do this easily, the plan previously mentioned of mounting large lenses in round rims should be adopted.

CHAPTER XVII

THE USE OF THE IMPROVED TEST CHART AND THE NON CYCLOPLEGIC CORRECTION

For a non-cycloplegic estimation we have combined the difficulties of the cycloplegic and the post-cycloplegic refractions, and in addition must be dependent in some measure upon purely objective findings.

There may be those who can, by retinoscopy, determine the astigmia within errors of 0.25 diopter and within five degrees of the axis, perhaps closer in large errors; and there are various expedients tending to unlock ciliary over-action. One is to dissociate convergence from accommodation by placing over the eyes under examination prisms, bases in. Now the patient in fixing at the point you select for retinoscopy—say this is at forty inches—the visual axes must be divergent. Having determined and recorded your retinoscopic findings, the corneal curves are measured on the ophthalmometer. The amount, if any, of the astigmic error also becomes part of the record.

In the chapters on "The Routine of Refraction Work" and "The Cycloplegic Correction" is given the technique which is equally applicable here, but we must ever have in mind the accommodational influences which may alter both axial and corneal findings. One may be sure, if marked discrepancies come out between the objective and subjective tests, that the ciliary muscle is playing tricks on us. How may we circumvent an over-action which will mask a hyperopia, induce an artificial myopia or make one already present appear greater, cause continued near work to be painful, and which may neutralize in part or in whole (dependent upon the degree) a corneal astigmia? Two methods are open to us.

The first is to determine separately the refraction in each eye, and then binocularly place over both, plus 0.50 diopter sphere and see if this blurs vision. If it does not, there is at least this much latent hyperopia or too great a myopic correction. Let the patient close the eyes and replace the plus 0.50's with plus 1.00's. Let the patient look again at the chart and ask, if while now blurred, there is a tendency toward clearing and possibly some of the letters on the next lower line are becoming visible. If so, replace the 1.00's with plus 0.75's. Often it will be seen that the line visible with the first monocular trial comes out clearly. If it does, and there is a cylindric element in the correction, go over power and axis again with the crossed cylinder, remembering that for every plus 0.25 diopter sphere addition there is a visual diminution of ten per cent. If the first addition of 0.50 diopter cuts off twenty per cent. and there is no approach toward vision clearing, it is inferable that the monocular findings are, at least, reasonably accurate.

There is yet another expedient which will reveal any latency. Place over the distance correction a pair of plus four spheres. If the patient can read clearly at a greater distance than twenty-five centimetres, there remains some uncorrected hyperopia.

At this stage there is a little trick with the cross cylinders which may sometimes be used to advantage, and especially so if the correcting cylinder is of more than fractional power. Over the lenses in place before the eye, superpose the crossed 0.25's with axes 45 degrees removed from the position of the correcting cylinder, let the effect upon clarity be recognized, and then shift over to 135 degrees. Ask which of the two positions give better vision. If either, shift the correcting cylinder toward the axis of the crossed cylinder which did this. If both equally blur, the position of the correcting cylinder is assumably correct. If the cylinder is a plus 1.00, the crossed 25's will shift the axis toward the axis so superposed seven degrees, with crossed 50's, thirteen. If the corrective cylinders be minus, the minus axis of the cross should be first at 45, then at 135; if plus, reverse the sequence. If an increased acuity of vision results or if there be a choice between the two positions, it is inferable that the axis of the correcting cylinder is not exactly placed.

The second method to unlock ciliary over-action is by the fogging method. The fogging is induced by over-correcting hyperopes or under-correcting myopes. The first test object is the astigmatic dial, and plus lenses are decreased in power until one set of lines come out black. If they do, it shows an astigmia, points out the meridian of least refraction, and indicates that the refractivity of the meridian at right angles to this should be equalized by the addition of minus cylinders. How strong these cylinders should be depends upon how many lines come out. If the vertical set alone, begin with a minus 1.50. It must be the rule to use the weakest lens which will equalize the clarity of both meridia. When this is accomplished, direct the patient's attention to the test letters and make such reductions in the spheric power as may be necessary to obtain the maximal vision possible. Then again is gone over power and axis of cylinder by methods previously described. With the newest forms of test cabinet the technique is essentially different. (For description of this, see chapter on "The Test Charts.")

In a work dealing purely with problems of refraction, nothing more than mention can be made of the difficulties arising when the illiterate, the child, the foreigner (knowing no English characters), the malingerer, the color blind or those deficient in light or color sense, or the amblyope, come up for examination. Provision should be made to meet the emergencies incidental to any or all of these, and the proper test chart will satisfy the requirements adequately. While clarity, and not size of the test letters, is the criterion applied in the determination of the refraction, it must not be forgotten that in hyperopia the effort of accommodation both in the distance and in the near, reduces the size of the retinal images. The correction brings forward the nodal points, and while now the images are of normal size, they appear magnified to the patient.

CHAPTER XVIII

THE ANOMALIES OF ACCOMMODATION AND THE PRESBYOPIC CORRECTION

Accommodation was one of the last evolutional ocular functions to be established as a racial trait, and in consequence suffers first a recession of activity. This attains its maximum in early life and gradually lapses as years advance. Donders who placed the reserve at the 45th year, as being no longer adequate for continuous near work was right, in a general way, but wrong when this function is tested out under modern scientific measurements, and often was he at fault when modern requirements for near vision are taken into account.

While the natural diminution of accommodative power, as a rule, follows a fairly regular curve, yet there are so many causes operative to alter this that it can not be taken for granted that a patient at any given age has his proportional amount remaining. I can recall one case of my own, a well-developed healthy girl, nine years old, who required a plus addition of 3.00 diopters before she could read at all. Her total power was zero, and she has worn bifocals ever since. Many, many times even with the static refraction corrected to a nicety does relief of eye strain fail to follow, because the refractionist assumes, on account of the patient's youth, that the normal reserve of accommodation must be present. Asthenopia may follow static, dynamic or muscular imbalances, and the ocular status is *not* determined until all of these factors have been weighed and valued.

I may not enter here into the multitude of somatic and reflex disturbances which alter static and accommodative conditions; for example, diabetes which increases the index of refraction of the vitreous so inducing or increasing a hyperopia; glaucoma or diphtheria, which cause paresis of the ciliary muscle. It is simply to be remembered that every muscle in the body participates in a somatic asthenia, no matter what may be the underlying cause. Note the painful vision and failure of accommodative sustension which follow acute illnesses. Note also the monocular accommodative loss which follows toxic or luetic damage to the ciliary ganglion. This lesion, however, gives evidence of its presence by anisocoria. The pupil on the affected side is larger and less active than its fellow.

Relative accommodation is also a late evolutional acquired faculty, and so while accommodation and convergence are associate functions they are not of necessity conjunct. Either may be thrown out of action without nullifying the other; for example minus lenses permitting clear vision in the distance, or again clear vision in the near without lenses, but with prisms superposed, bases in. In both instances we have accommodation without convergence. There is, however, a certain acquired relationship between the two which may not, with impunity, be rudely disturbed. There are association tracts between the centers for convergence and accommodation, and the latter function is more easily sustained if proportional balance is established between them. An uncorrected hyperope has a proportional accommodative excess; an uncorrected myope, convergenal predominance. It is axiomatic that comfortable near vision can not be sustained without ample accommodative power, and the proportion between cases of accommodative insufficiency and accommodative excess (spasm) is greater for the former.

Accommodative insufficiencies may be roughly divided into two classes: Type *A.*, premature presbyopia; and type *B.*, subnormal accommodation. A subdivision of the latter is one with normal accommodation for age, but with lack of sustaining power except for short periods. Under the first grouping, type *A.*, the patient's eyes are older than his years. He has all the symptoms of presbyopia, with recession of his punctum proximum, but with little or no asthenopia. He is simply inconvenienced, but not uncomfortable. It is different with type *B.*, under which the patient is both hurt and handicapped by his infirmity.

One occasionally meets with a case of accommodative inertia where the function gets into action slowly and is as tardily released. These patients have to wait an appreciable interval before print comes out sharply, and on looking up, for distance vision again to clear.

Accommodative excess or spasm is mostly due to systemic or reflex causes. I have seen cases where impacted teeth, pulp stones, or intranasal contacts was the underlying cause, but more frequently is it intense and prolonged use of the eyes at close range. Spasm of accommodation is comparatively rare, is easily mistaken for myopia, and the degree may be estimated only under complete cycloplegia. These patients should be subject to a critical analysis of all their bodily functions as well as to an exhaustive examination into their ocular status, including not only refractional errors, but innervational or actual motor imbalances. It should not be forgotten that accommodative power may be unequal in the two eyes and that therefore the test for relative accommodation (both eyes functioning) should be the last and not the first.

The range and region of accommodation are not synonymous terms. An emmetrope and a myope might have the same amplitude (range) of accommodation, but the region (the spacial intervals between which clear vision is possible) would be much smaller in the latter. What interests us as refractionists, however, is the amount of accommodation available for continuous near work. To determine this the patient, glassed with his distance correction, the eye not under test being covered, is asked at what point the test object, as it is gradually brought nearer, begins to lose distinctness. This sounds easy, but in actual practice it is not, and especially is it apt to be fallacious with the binocular test, and in any case greatly so if vision is less than sixty-five per cent of the normal. If small-sized type be used as the test object, the association of form rather than clarity will permit of reading at closer range, and so vitiate that test. With many patients this is a matter of faith: "The evidence of things unseen."

The test object to be used is a minute black line engraved upon a white card. Prince's meter rule is employed and the card brought progressively closer until the line loses sharp definition. At this point record should be made of its distance from the anterior focal point (14 millimetres) of the eye, measured in centimetres; one hundred divided by this gives the accommodative power in diopters. The test is repeated for the sake of accuracy, and gone over in like manner in the other eye. If, for example, it is alike in both eyes, the binocular test may be made for relative accommodation. Here care is to be exercised that a doubling of the line from

TABLE OF ACCOMMODATION

AT VARIOUS AGES

In D and tenths. Near point reckoned from anterior focus of eye (14*mm* in front of cornea).

Age	Accommodation		Maximum
	Minimum	*Mean*	
8	11.6	13.8	16.1
9	11.4	13.6	15.9
10	11.1	13.4	15.7
11	10.9	13.2	15.5
12	10.7	12.9	15.2
13	10.5	12.7	15
14	10.3	12.5	14.8
15	10.1	12.3	14.5
16	9.8	12	14.3
17	9.6	11.8	14.1
18	9.4	11.6	13.9
19	9.2	11.4	13.6
20	8.9	11.1	13.4
21	8.7	10.9	13.1
22	8.5	10.7	12.9
23	8.3	10.5	12.6
24	8	10.2	12.4
25	7.8	9.9	12.2
26	7.5	9.7	11.9
27	7.2	9.5	11.6
28	7	9.2	11.3
29	6.8	9	11
30	6.5	8.7	10.8
31	6.2	8.4	10.5
32	6	8.1	10.2
33	5.8	7.9	9.8
34	5.5	7.6	9.5
35	5.2	7.3	9.3
36	4.9	7	9
37	4.5	6.7	8.8
38	4.1	6.4	8.5
39	3.7	6.1	8.2
40	3.4	5.8	7.9
41	3	5.4	7.5
42	2.7	5	7.1
43	2.3	4.5	6.7
44	2.1	4	6.3
45	1.9	3.6	5.9
46	1.7	3.1	5.5
47	1.4	2.7	5
48	1.2	2.3	4.5
49	1.1	2.1	4
50	1	1.9	3.2
51	0.9	1.7	2.6
52	0.9	1.6	2.2
53	0.9	1.5	2.1
54	0.8	1.4	2
55	0.8	1.3	1.9
56	0.8	1.3	1.8
57	0.8	1.3	1.8
58	0.7	1.3	1.8
59	0.7	1.2	1.7
60	0.7	1.2	1.7
61	0.6	1.2	1.7
62	0.6	1.2	1.6
63	0.6	1.1	1.6
64 to 72	0.6	1.1 to 1	1.6

BINOCULAR ACCOMMODATION

The above are the limits for each eye tested separately. For binocular accommodation the values here given for the mean limits should be increased by 1.5 D for ages 8 to 15; 1.25 D for ages 15 to 20: 1 D for ages 20 to 30: 0.75 D for ages 30 to 40: 0.5 D for ages 40 to 50: and 0.3 D for ages above 50.

a convergence insufficiency is not mistaken for impaired definition. Comparison is now made with Duane's table for normal averages for age of patient as shown above.

Any marked variation from the average is indicative of subnormal activity and may call for accommodative help for near work by plus lenticular addition to the distance glasses. The premature presbyope, type *A.*, should have his age disregarded and such lenses given as will permit continuous near work in comfort. The asthenopic subnormal cases must have general treatment as well as ciliary assistance. If causes be removed and a better somatic tonus be attained, less plus may be needed or entirely discontinued. The presbyope who, by virtue of his age, is naturally presbyopic, presents a problem into which enter many factors aside from the one purely optical. The first measurement is his reach, not his range. If he is long-armed, his reading distance is farther away and in consequence less additional power is required than would be were his arms shorter. Then again, people of the same stature have different habits. Measure always the customary reading distance. Remember also that the punctum agendi and the punctum legendi are rarely coincident. For instance, a woman does not read and sew at the same distance. Her near lenses are a compromise, a quarter or a half diopter weaker than would be prescribed for reading alone. As has been said, there is, in every patient an equilibrium between convergence and accommodation to which they have become accustomed, and while this status admits of some variation, it may not be wholly disregarded.

To determine what shall be a comfortable presbyopic correction, test out the muscle balance at the reading point by inducing vertical diplopia (six degrees prism base down over one eye) the patient to wear his distance correction only, the test object being a dot on a white card. Note if the patient be esophoric or exorphoric. Re-test with the tentative reading correction and note if there be any alteration in the former relationship of the muscle imbalance. If the patient was esophoric on the first test, and less so on the second, a full correction may be ordered; if exophoric on the first and more so on the second, only the weakest correction will be acceptable. To verify this assumption, re-test with the cross-lines later described in this chapter, while the prism is still in place, calling the patient's attention first to the upper and then to the lower image (always at the reading distance). If the vertical lines are the blacker, reduce the spheric power; if the horizontal, then increase until both lines are equally distinct.

If intended for a special purpose, such as plastering, carpentry work at the bench or piano playing, about plus 1.50 is added to the distance correction. The carpenter can use bifocals, if necessary. The other two must have whole lenses. The problem of the book-keeper presents peculiar features; particularly is this true if he have to take off his figures from several books at differing distances. In the last instance, he may have to use trifocals. If he needs no distance correction, his problem may be solved by bifocals. Only rarely can he use whole lenses. The shop-keeper who must see the labels on his shelf goods and the price marks on the goods themselves is another phase. And the band man who must see his music and the street where he is walking, demands another style. The presbyope with a high hyperopic error becoming manifest may need a correction to be used when shaving. Ascertain how far he stands from his shaving mirror and give him an addition of a focal length of twice this distance. For example, if the mirror is 20 inches away, a plus 1.00 diopter will give a sharp image of the reflection in the glass. All this will be taken up in detail under "Bifocals."

How shall we know if our tentative correction is just of the right power? In the first place, the amplitude of accommodation is taken for each eye separately. It is to be remembered that for binocular vision the accommodation is somewhat greater, the amount varying with the age.

Presbyopes glassed for the first time should have under rather than the full correction. They no longer get the innervational impulse which associates convergence with accommodation and there ensues a temporary insufficiency of adduction. In this connection, patients who have an essential insufficiency of convergence will reveal their condition in the binocular test for range of accommodation; the fine black test line will become doubled before the edges grow fainter in outline. Be sure your questions make this clear, that the patient may discriminate between these phenomena.

The normal point of convergence lies between 9 and 4.5 centimetres. If the line doubles much farther out, say at fifteen centimetres, one must give this presbyope the weakest lens which he can utilize for his reading distance, and as he gets older and must have stronger lenses, they must be combined with prisms bases in. Leaving this comparatively rare condition aside from consideration, and knowing how much reserve of accommodation is present, we may assume that only two-thirds are available for constant use; and assuming also that all that is required is reading ability, we put on the addition; and the first question is not, how near, but, how far away can the print be held and still be legible, using a size of type suitable for the distance at which it is held. Having determined this distance, the patient is asked to bring slowly the print nearer. Note at what distance blurring occurs). (This should be at about 25 centimeters.) These are rough tests, of course. It remains to find the exact addition required. The patient is now asked to hold the print at the distance he prefers or is accustomed to use, and to look at a card, at the same distance, upon which are drawn four black lines in juxtaposition but at right angles to each other. (These cards can be obtained from the A. O. Co.) If the vertical lines are the blacker, the correction is too strong; if the horizontal, too weak. As a mnemonic aid, B. V. D.'s suggest Vertical Blacker Diminish. Whatever changes that may be necessary are now made until the distinctness of both lines are equalized. We have now determined the binocular correction, but this is not all. A right-handed man will get his impressions from his dominant eye (the right), and the lines be equalized even if the left eye is not properly corrected. With the same card and at the same distance, induce vertical diplopia, say with an eight degree prism, base down, over the right eye. He will now see two cards. Ask him to look at the lower (the left eye viewing this). If the lines are not equalized, make them so. Repeat this test with the upper image. Equalize these lines if necessary. Now test out with print binocularly, and comfortable reading ability will have been established.

Almost never is it necessary to add more than plus 2.50 to the distance lenses except when vision is very poor and the patient must hold his reading matter closer to get larger retinal images. A plus 2.50 gives clear images at its focal distance, sixteen inches, and this addition is necessary only when there is little accommodative reserve. Most patients are more comfortable with less, and can use part of their ciliary power. Elderly patients will do better with the stronger corrections, as a rule, but again must be remembered the fact that there is no absolute inflexibility to the curve of accommodative diminution.

It does not necessarily follow because a presbyope accepts a cylinder in his distance correction, that he will do so for his near. The contraction of the pupil which goes with near vision may cut off an astigmic zone, or if distance cylinders have never been worn, his center for visual perception may refuse to adapt itself readily to the corrected ocular image. When in doubt as to whether there be beginning presbyopia or subnormal accommodation, take the lined card, held at the reading distance, and superpose the distance correction with a crossed cylinder (.50 combined with 0.50) with plus axis at 180. If both lines come out distinctly, we may assume an accommodative sufficiency; if the horizontal only, help is needed.

What shall we do for the unfortunate, presbyopic or otherwise, whose vision is reduced to twenty per cent. of the average? No ordinary glass will give him reading ability or even comfortable distance vision. For such cases one must go beyond usual lenticular corrections. The one great drawback to this form of visual aid is its unsightliness. The optical principles involved are those of the Gallilean telescope. The lenses are mounted in a metal shell shaped like a truncated cone twenty-three millimetres long and thirteen millimetres at the larger end. Ordinary spectacle frames are not suitable, so the two tubes must be mounted in specially constructed holders. Incorporated in the lens system of this telescopic form is the patient's distance correction. With this worked out as carefully as possible, the makers will add such lenses as will give a magnification of from 1.3 to 1.8 diameters. This materially improves distance vision; and for near, amplification up to 4.5 diameters may be obtained by further lens attachments. If vision is not too low, and if accommodative assistance is needed, there are removable caps which may be adjusted for near work. These lenses are made by the Zeiss Optical Co., who also make special trial lenses for use in these difficult and unusual cases. Not only must the refraction be accurately measured, but the frame dimensions must be taken with the greatest care.

In high myopia spectacles with a magnification of 1.3 will give a retinal image thirty per cent greater. The field, however, is somewhat restricted, covering only about forty-five degrees. Any associate astigmic error can be compensated for in the lenses. For use at the reading distance, the converging angle of the tubes must be so co-ordinated that, at the distance selected for use, running from thirty-three to twenty centimetres, images included in the field of vision shall overlap. Even with a visual acuity so low as eleven to fourteen per cent, sufficient magnification can be obtained for reading. But in this case, binocular vision is impossible and reading must be done with one eye only. If vision is low but not sufficiently impaired to permit of the use of both eyes, then two pairs of telescopic glasses are required, one for distance with parallel axes, the other for reading with axes converging.

CHAPTER XIX

REFRACTIONAL CHANGES INCIDENT TO ADVANCING YEARS

By implication one might think this title as applicable to the aged only, but its laws run through from infancy to life's closing phases. The baby is born with eyes that see not; it has retinal images, but no visual perception. The store-house for visual memories is empty, and co-ordination between the visual centers is yet to be established; that is to say, it has monocular vision only and no sense of perspective. The eyeball is short, the lens nearly spherical and the ciliary muscle weak in participation with the somatic musculature.

As the child grows, so do these characteristics of underdevelopment undergo changes. The first sign of dawning intelligence is binocular control. The communication fibres between the cunei begin to functionate, and now the child is acquiring binocular single vision. Between the sixth and the eighteenth month this function becomes permanently established. The child is hyperopic (about 1.00 diopter). Along about the eighth year it attains its maximal ciliary power and its hyperopia tends to lessen. This is the age at which the child should begin school-life, not before, and as a precautionary measure his refraction should be gone over under a cycloplegic. High hyperopia is an effectual bar to easy mental acquisition. Whatever may be the cause of myopia, it is apt to make its appearance along about this time. If it does, and goes uncorrected, it works disaster to a correlative development of brain and brawn—the latter suffers. If it be true, and I feel sure it is, that personality and character are integral parts of a harmonious relationship between soma and psyche, then becomes imperative the conservation of the body which houses this mind. If an ametropia be found in a child, no matter of what type, hyperopia (excepting the minor degrees), myopia, including even the small errors, or astigmia of even the smallest amount, it should always be corrected.

After the first cycle (24 years), barring intercurrent maladies, there is a second cycle of comparative stasis (another 24 years) in which there is to be expected little change in the static refraction. As the third cycle of 24 years draws near its close, changes incident to age are shown in many ways. Vision lessens in acuity; changes occur in the astigmic error to mark this period; accommodation becomes nearly abolished; any latent hyperopia becomes totally manifest; and lenticular sclerosis diminishes myopia to a minor degree and increases slightly more an existent far-sightedness. Changes also occur in the astigmic error to mark this period. If the correction has been a plus cylinder with axis in the vertical meridian, it begins to shift toward the horizontal, sometimes nasalward, sometimes temporalward, and at last comes to rest on the 180th meridian. But the amount lessens with each shift, so if the cylinder was comparatively weak, the astigmia disappears entirely.

A non-astigmic eye will develop an error, and this is always "against the rule." A myopic astigmia with the rule remains so, but diminishes in amount, and should its axis have been removed from horizontality, it tends to assume this position. A myopic astigmia against the rule has no tendency to shift, but the amount increases and the astigmia inclines to become a mixed error, with low power plus spheres acceptable. A hyperopic astigmia againt the rule remains so, but becomes greater instead of less. Between these major changes there are many minor ones of like kind which may occur. What should be stressed is that from youth to age the refraction is in state of flux. Often will be asked: "Doctor, how often should I change my glasses?" The answer should not fix a definite period, but should include advice based on the probabilities heretofore mentioned. The wisest reply is: "It is impossible to tell just when a change will be necessary, but should you experience any return of the discomfort for which you consulted me, that is your cue for another examination. The fault may not lie in the glasses at all, but it certainly means that something needs attention."

CHAPTER XX

THE OPHTHALMIC LENS

It is a far cry from the day when "specs" were selected by the prospective wearer from a basketful, and his choice fell on those with which he could read, how well did not matter. Little or no attention was given to distance lenses, and those for near work were mostly biconvex. In the cheapest grades these were not even ground, but pressed out in a mold like bottles. The glass from which these lenses were made was of the same composition as was window glass. The manufacture of optical glass of a uniform dispersive power was then in its infancy. One should think that such pernicious methods of making and selection were long ago relegated to the limbo of forgotten things—that they are not *vide* the ten-cent stores.

The modern scientific ophthalmic lens is not only made from a glass always of the same optical qualities, but its curves are computed to eliminate the aberrations always associate with the older types.

Let us see what happens when either a plus six or a minus six of bi-spheric curvatures is placed before the eye. So long as the axial ray alone is utilized, these represent respectively, but only approximately, their indicated actual or virtual foci; but just so soon as the line of vision falls eccentrically, at once begins an aberration, and as the angle becomes greater, an increasing error which includes both spheric and cylindric powers. Take the plus six, for example. At its periphery it now has a power of plus 6.98, incorporated with which is a cylinder of 4.80 diopter at axis 180. The minus six at the same angle is equal to a minus 6.50 diopter sphere combined with a minus 2.00 diopter cylinder, also with axis at 180. It is evident that clarity of vision falls off when the lens is used at this angle, to say nothing of the harmful eyestrain produced. The difficulty cannot be overcome by tilting the lens for now the aberrations affect distance vision.

Besides this there enters another factor, and that is the equivalent power of the lens, unless back focus or vertex refraction is utilized. A biconvex lens of plus 6.00 diopters does not have a focal length of 16.66 centimetres unless made infinitely thin. If it have a central thickness of 3.4 millimetres, its focal length is 16.75 centimetres (less than 6.00 diopters). And if made of larger size and in consequence thicker at the center, it is even less than this. The reverse obtains if lenses of the same number are made as deep menisci. Now they have a focus less than 16.66 centimetres, and the larger they are, proportionately shorter is the focus. In other words, they increase in strength.

Neither power nor size of image is the desideratum in an ophthalmic lens. We are concerned only with the *position* of the image. Consequently it is the back focus, not the focal length (power) which is of importance. In weak lenses these (vertex refraction and power) are nearly co-incident, but it makes a great difference if strong lenses must be prescribed.

The first improvement on the old biconvex form was the making of the so-called periscopic lenses. The word means "see around," but does not clearly indicate whether the patient preferred to "see around" the glasses, or through them. The back surface had a minus curve of 1.25 diopter, the front a plus proportional to the power; for example, a plus 2.00 diopter had an anterior surface equalling plus 3.25. For minus powers the outer curve was plus 1.25. This type of lens, while an improvement, did not minimize to an appreciable degree the peripheral aberration; so later the deep meniscus (minus 6.00 posterior curve), or the toric form (where cylinders were incorporated), came into use. Even this did not wholly make the lenses truly periscopic, but in the weaker powers (plus 1.00 or plus 2.00) reduced the aberrational errors to a negligible quantity.

Let us see what happens, under different forms, to the plus 6.00 and the minus 6.00 in peripheral vision. Biconvex 6.00 equals 6.98 on a 4.81 cylinder; plano convex, plus 6.33 on a plus 2.13 cylinder; periscopic, plus 6.15 on a plus 1.48 cylinder; mi-coquille, plus 5.79 on a plus 0.15 cylinder. In the minus power, biconcave equals minus 6.50 on a minus 2.00 cylinder; plano-concave, minus 6.17 on a minus 0.88 cylinder; periscopic, minus 6.03 on a minus 0.56 cylinder, and lastly minus 5.70 on a minus 0.17 cylinder.

It remained for Dr. Moritz Von Rohr of the Zeiss Optical Company to work out the mathematical formula for a lens which would be almost correct in all areas, but even he could not attain the impossible. By an exact computation, giving proper values to power, thickness and index of refraction, a lens can be made free from oblique spheric or cylindric aberration, but not from both. In general, speaking of medium power lenses, if the spheric aberration is entirely eliminated the cylindric error increases and vice versa. It is better, however, to eliminate the spheric and leave in a little cylindric error, which at an obliquity of 30 degrees is practically negligible. Speaking generally for distance lenses of medium power, the meniscus or toric form on a minus six base is better than the other bases running from three to nine; but for the *best* every power needs to have a separate computation.

We are concerned also with other inescapable factors in the ophthalmic lens: one is the cost, the economic factor, the other is that of the cosmetic value. Lenses of very deep flexures are not sightly on the face of the wearer. One may start with this axiom—mathematical exactitude is impossible, but in practice one may attain approximate correction with a negligible error up to thirty degrees eccentric to the optical center of the lens.

For a given power a meniscus may be selected in which spheric and cylindric errors are very small but, in general, if either is reduced to zero the other gets too large. The American Optical Company in the Wellsworth Tillyer lens have reached the happy medium and have so correlated the flexures that the residual marginal errors are negligible and at the same time there has resulted a lens of graceful proportions.

This matter of lenticular exactitude is of the greatest importance. If it be true that a myope should have the full correction, the lenses unless corrected for aberration, cannot be worn in comfort, and only a lesser correction will be tolerable. Less than full correction is bad practice, but only recently have the reasons for the myopes' discomfort been realized. Turn back, and read what has been said of the optical properties of a minus six biconcave lens in oblique vision. No eye can overcome an astigmia of 2.00 diopter, and besides this, there is an additional 0.50 diopter of accommodation forced into action. Even a deep meniscus possesses an irritating astigmic aberration, but this power-lens can be so ground as to cut the error down to 0.04 diopter. Incidentally, in very high myopia, minus 19 to 20 diopter, the best form of lens is a plano-concave. It is an exceedingly intricate problem to pick out, for any specified power, the plus and minus flexures which shall minimize the undesirable aberrations. They can be reduced to negligible quantities, and that is enough for the refractionist to know. When we get into the high plus powers it is no longer possible to attain our object through spheric surfaces; one curve must be paraboloid—*i. e.,* a departure from a true spheric surface.

It has been said that the trial case is the court of last resort. It isn't true. It is the High Court of Justice in interpreting the laws of refraction, but the patient has the right of appeal to a still higher court to determine if the application of these laws does not run counter to the Constitution (I mean the patient's).

This little excursion into the property of lenses is wholly pertinent to refraction work. One must know these things so that exact instructions may be given to the lens-grinder and not let chance govern the form of the glasses supplied on our prescriptions. It is an easy matter for errors to occur after the prescription goes to the maker. One should never assume that the lenses are correct until they have been checked up personally for power of sphere and cylinder, axis and centering on a lensometer. My own choice is Lloyd's Axometer. It is the height of folly to go to all the painstaking care necessary for accurate refraction work, only to have it upset by errors in grinding or mounting the lenses. These happen more often than one would surmise, and no responsibility should be assumed until lenticular accuracy has been verified. Patients should be told this and made to report, with their glasses on. It is surprising how the percentage of error drops when the optician knows you do this, and use an accurate meter on his lenses.

There are other things besides form to be taken into account, and one is surface finishing. If this is not properly done, one of two things happens, over or under polishing. If over, the proper flexure is disturbed and an undesirable aberration results; if under, we get what is known as a "gray lens." To detect these faults, we use a small spot-light (a perforated cover over an electric light). The over-polished lens displays a central diffused glare. The gray lens is viewed obliquely and the faint haze at once becomes evident. At this place it is pertinent, but not wholly relevant, (because double vision lenses are yet to be considered) to describe how may be detected the two faults which occasionally occur in a fused bifocal.

One of these is inherent to weak power distance and high power near additions. This is a chromatic aberration at the margins of the inset. The other is failure of exact fusion. To see these, we look through the lenses obliquely at the spot of light, the rest of the room being in darkness. If the first is present, spectral colors appear. If the second, little gray spots come out where the reading segment is inserted.

A third source of trouble lies in the fact that crown and flint glass have not a common fusional temperature. Any error of technique will cause a distortional flux at the junction point and introduce a disturbing element to clear vision.

All of these things just mentioned interfere with clear and comfortable vision. If a lens looks smooth and feels smooth, it ought to be smooth, but is it? As a matter of fact it isn't, and with the usual methods cannot be made so. On cross-section under the microscope it looks like a wash board even after the last fine grinding, and all that the final polishing does is to lessen the depth and round off the crests of the ridges. To attain the maximal smoothness possible, hard polish must be applied. This not only takes off the crests of the ridges, but wholly obliterates the hollows, leaving a perfect flexure and polish. Soft polishing is done by applying wet broadcloth over the grinding tool and upon this sprinkling polishing rouge. In hard polishing the rouge is incorporated with a hard wax, and this is molded on the lap by heat to its exact curve. Look through two lenses alternately, one with soft and the other with hard polishing, and note the exquisite clarity of the latter.

CHAPTER XXI

THE BIFOCAL LENS

Here we have a problem into which enter the difficulties of both static and dynamic refraction together with the complications incident to the mechanical carrying out to fulfillment of the conditions embodied in these two states.

There enters also the matter of prismatic displacement incident to the line of vision falling eccentric to the visual axes, and this, with the other factors, makes their reconciliation next to and sometimes impossible. It is not enough to simply determine the static refraction, and then order blindly plus additions for reading.

There are many types of bifocals. All have some disadvantages, some more, others less, and some have advantages not possessed by the others. For instance, the split bifocal, the old Franklin lenses, can be made to fulfill nearest the optical requirements, but what they would look like does not admit of polite comparison. To make a bifocal scientifically exact and sightly at the same time is next to impossible, and the refractionist should know just what has been done along these lines that he may be able to select for his patient that which will best meet his needs.

The economic factors come into play also. The better type of bifocal is expensive, the best still more so, but it is well to know that the cheapest form, the cemented, can be made to cover the optical requirements with only a sacrifice of sightliness.

To supply the need for accommodative assistance in the ametropic presbyope has been long recognized, but how best to do this is the achievement of yesterday only. / We can not turn back the shadow on the dial of Ahaz, and with advancing years the accommodative loss will hamper us in the middle distance and finally the bifocal will give only a punctum remotum at infinity, and a punctum proximum at the focal length of the reading segment. An abortive attempt was made to overcome this difficulty by a multifocal lens. It had no reading inset, but was so ground that when the line of sight passed from above downward, it met a surface of increasing power. The formula for the lens was supposed to be secret, but the posterior surface must have been ground on a conical curve. The peripheral aberration in parallels to this conic base must have made this lens unwearable and unbearable.

The trifocal lens may fill a long felt want, and it does so in certain cases. When there is need for clarity in the middle distance, it is a great comfort. Where the intermediate addition shall be placed depends upon the needs of the wearer. For instance, the shop-keeper who must be able to read the labels on his shelf goods, say at four foot distances, has the segment at the top of his glasses for the middle distance, and below another for near. The book-keeper who needs to transcribe data from books placed on his desk at varying distances, may have the middle distance correction at the sides or half-way down the lens. The same would apply to an artisan at fine work whose tools were arranged at arm's length.

The history of the bifocal is of purely academic interest, but a brief review may not be out of place to serve as a criterion of optical progress in lens-making.

Benjamin Franklin was the father of the bifocal that bears his name, and of something animate that didn't. At any rate, he may be forgiven for the last because of the benefits and comforts brought to mankind by the first. Dear old Ben builded better than he knew. He took his near and distance lenses, cut them in halves on the long axis, and mounted these in his spectacle rims. If his knowledge of optics had gone a little further, he could have cut his semi-ellipses from the mid-portion of the lenses, thus making distance and near monaxial; and if, by any chance, he was astigmic, with distance and near axes non-symmetric, he could have overcome this difficulty which no other type of bifocal can, unless the Perfection type be used.

This form has fallen into "innocuous desuetude." It was made by cutting out a segment from the distance lens and inserting into this space the reading correction. They could be used only in rimmed lenses, were very unsightly, and after a short time the line of junction became filled with collected dust.

The next essay, from the cosmetic standpoint, was a whole lens of such power as was needed in the near, and the lesser power for distance obtained by grinding away part of its upper half. This lens was sightly, but optically atrocious. Induced prismatic and aberrational defects soon caused its disuse, and in its place appeared the cemented form.

Optically this type is much better, but it is conspicuous. Conceit is a bad thing, but self-respect is laudable and we owe it to ourselves to appear as well as possible. This is the age of the young, and anything which advertises the fact that we are growing old is a handicap to material advancement. Perhaps its one strong talking point is its cheapness. Its one strong optical advantage is that by proper grinding the prismatic effect of looking eccentrically through the distance lens can be effectually overcome.

As a rule the optician pays no attention to this, and here it is he gets in his fatal work. The wafers are made in quantity, are picked out from a labelled box, and no concern is given to anything except power. If you will look at a horizontal line co-incident with the long diameter of the applied wafer, and there be no prismatic displacement, the line through lens and paster will be continuous. Usually it is not, but it should be.

It is of vital importance to the comfort of the wearer that there should be no prismatic imbalance, and particularly is this true in myopes and anisometropes. There is a simple rule for making and applying optically correct pasters. Take the distance in centimetres from center of distance lens to center of paster, multiply this by the dioptric power of the distance lens (in its vertical diameter), and divide the sum by the dioptric power of the paster. This will give prismatic power to be overcome. Add this figure to the vertical semi-diameter of paster in centimetres, and multiply by two. This will give the size of the lens from the quadrants of which the pasters should be cut. For example, take for distance a minus 5.00 on a minus 3.00 axis, 180, with a plus 3.00 addition; the center of which falls, say, 0.7 centimetres below center of distance lens. Power in vertical meridian eight diopter multiplied by 0.7 equals 5.6. divided by 3. (power of add) equals 1.87, adding semi-diameter 0.70 equals 2.57 multiplied by two equals 5.14.

The directions, therefore, to the lens-grinder should be:

Make a meniscus of 3.00 diopter power (plus 5.00 external curve on a minus 2.00 internal) five centimetres in diameter worked to a knife edge at the periphery. Mark this off into quadrants and spot them 1.87 centimetres from the optical center of the lens on the mid-radial line. Cut the lens into the quadrants so marked, and from one finish up the paster. This cemented base up will give a combination free from prismatic error. That this lens is radically wrong in other respects (aberrational defects) does not enter into the problem, but speaking broadly cemented bifocals should be employed only in low powered spheric corrections. Inherent to its method of construction there are so many unwanted qualities in a cemented bifocal that it has fallen almost entirely into disuse. Taking its place are the semi-invisible types which are known by their trade names, Kryptok and Ultex.

In the Kryptok the additional power is obtained by fusing into a crown glass blank a flint glass inset. This being of a higher index of refraction will give greater collective power when ground on the same radius of curvature as the distance lens. As the toric form of sphero cylindric lens is now almost always employed, the reading segment of the Kryptok lens goes on the outside. It must go on the spheric side in all cases, so the inner curves are on a minus toric base.

The Ultex addition is ground integral with the spheric curve which may be on either side of the lens. Where it shall be placed is dependent upon the distance formula. For ordinary prescriptions it is placed on the inside.

The main drawback to the Kryptok is the chromatic aberration which may occur at the margins of the inset. If the distance power is low and the addition high, it is sure to occur. It may be partially but not wholly overcome by making the low sphere into a very deep meniscus, and the reading inset small. Within reasonable limits of refractional error and reading additions, this lens should be ordered in myopic cases. The excentric prismatic influence of a minus lens (prism base down) is minimized by the Kryptok inset, and accentuated by the Ultex. The reverse obtains in hyperopic cases. Here the Ultex is much the better lens.

Much has been done lately to the improvement of both Ultex and Kryptoks. Formerly, one could obtain the Ultex addition only on the inner curves of the lens; if this was a minus six and a plus two addition was called for—then the latter curve was a minus four. The outer surface of the lens could be ground spheric or toric to meet the power ordered for distance reading. To overcome peripheral-aberration it often became necessary to grind the inner surface on a minus toric curve. Now for additional plus in the near, the reading segment may be ground on the outside and be of collective and not dispersive value.

The old time Kryptok had inherent to the optical principles governing its construction many disadvantageous features. If the reading addition was strong and the distance power weak, the depression for the flint insert had to be ground on so deep a minus curve that of necessity this made the lens too thick, the reading area small and the sharp flexure, at the junction of crown and flint, induced distressing chromatic aberration.

Since the foregoing was written a new type of fused bifocal has come upon the market, in which the distressing chromatism has been reduced to the minimum possible and the error so lessened as to make it a negligible factor.

There are mechanical and optical reasons why absolute achromatism is a practical impossibility in a fused bifocal. If we try to eliminate the color aberration by using, for the reading addition, a glass of nearly equal dispersive power with that of the distance portion, the index of refraction must be proportionately lower than the flint glass usually employed. In consequence, the seat for the reading inset must be ground on a higher minus curve, with resulting sharp flexure at the edge.

The prismatic effect, of necessity, produces a faint marginal color fringe to the inset. Of minor, but still necessitous disadvantage is the greater imposed thickness of this lens.

In the Dualuxe we attain thinness by applying the principles of the achromatic lens, namely the fusion of a plus crown on a minus flint combination. The three factors incident to the computation are the correlation of the indices of refraction of the glass composing the distance and the near divisions of the lens, and the lenticular flexures incident and proportional to the reading power to be added. The index is fixed for the crown glass at 1.53, for the flint at 1.69. The ratio, therefore between these two is as 1.00 to 0.318. In other words, a piece of flint glass of this index ground on a plus one lap, whose curve is computed for the lesser index, will turn out a lens of plus 1.318 diopters. This ratio, however, does not hold for high powers, and here a relation of 1 to 3 is utilized.

This is the rule for determining what shall be the flexure of the distance lens and that of the near segment. For each diopter of power to be added, multiply such addition by three, subtract the product from the power of the outer curve of the crown distance portion; the result will represent what plus curve shall be given the seat for the flint reading inset, and consequently what minus curve shall be given its posterior aspect. For example, a reading addition of one diopter is to be incorporated with a lens whose outer curve is of 8 diopters, eight, minus 1 multiplied by three equals five (8—(1X3)=5). Into the plus five seat the button, having a minus five curve, is set. Its index, however, being 1.69, it has a total minus power of 6.50 diopters (5 X 3 = 1.50 plus five). The five plus curve of the seat neutralizes all but 1.50 diopters, leaving this minus remainder to be subtracted from the total power obtained, in the reading segment, by grinding an eight diopter curve on a glass of 1.69 index. The power so obtained is equal to 10.50 diopters. Subtracting from this our minus 1.50 residue, gives a bifocal whose distance power is 8 diopters and whose power for near is nine, thus giving the one diopter reading addition we required.

A further advantage in a lens of this type is its capability of being ground exceedingly thin without grinding into the inset when finishing up the inner curves. Thinness of the lens must be sacrificed when the inset is on a plus instead of a minus flexure.

To keep in the fore-front of modern ophthalmic progress, one must be constantly on the alert. The semi-invisible bifocal, whether of the fused or one-piece type, is under constant experimentation, and the next step will be a lens of low visibility, devoid of peripheral aberration, color free at the inset, and so ground that distance and near divisions shall be monaxial.

Common to the foregoing types of bifocals is the area of lost vision at the junction of the near and distance divisions, and the disturbance of spatial relationship in things seen through the lower halves of the glasses. At the junction there is doubling of objects on the horizontal plane, the upper of the two being a false image; in consequence, in going down-stairs, the tread seems nearer than it really is. We expect to land where the tread is not, but if we finish up at the bottom of the stairs, this will no longer be embarrassing. This difficulty has been overcome by making bifocals monaxial. They are not so sightly, as the reading portion must be depressed below the level of the distance part of the lens. By monaxial is meant that the radii for the near and distance curves are on a perpendicular common to both. This obviates the defects that have been mentioned, and still better makes these lenses comfortable in anisometropia and saves the refractionist the intricate calculations otherwise necessary. The makers claim that this lens obviates the difficulties inherent to bifocals in anisometropes. I can accept their contentions where the spheric errors are unequal or the cylindric axes vertical or horizontal, but for strong oblique astigmic errors, I doubt if monocentricity can be so obtained.

All this elaboration may seem supererogatory in a work on refraction, but is it? Suppose you had a case where the right eye took a plus 4.00 cylinder at 180 for distance, the left a plus 0.50 sphere and a plus 2.00 addition was needed for close work, and you wanted them made up in bifocals. It would not be enough simply to specify these powers on the prescription. If the lenses were 34 millimetres in vertical diameter, the ordinary reading addition would be 15 millimetres in size (vertically) and the visual line falling in the center of this would be 9.5 millimetres from the center of the distance lens. At this point the prismatic effect (deducting that from the other lens) is equal to 3.25 with its base up. Now this prismatic addition must be ground on the reading segment of the right, or the same prism strength base up on the other lens. Incidentally, if possible to avoid it, don't use prism additions base up in any type of bifocal. They are unsightly to begin with, and give rise to annoying reflections not only from the edge of the glass, but forcibly and often profanely from the patient, whose vanity is wounded. More than this they are optically not the position of choice. We look down oftener than we look up (of course physically is meant) and aid to the depressors is more logically applied by prisms base down, than by placing these base up over the other eye.

To correct our hypothetical case, several methods are applicable. If inconspicuousness is desired, our only recourse is an Ultex with reading addition and prism power ground on the right lens. Kryptoks are barred, as it is impossible with these to add prism powers in the near. Cemented bifocals may be used, and these, if well made, do not show much. The best possible solution is the monaxial, for in this lens no prism addition is necessary. While this is essentially correct in the instance cited, it is not true in cases of high astigmia at oblique axes. Here we must have a prismatic power ground on the reading segment, because oblique cylinders eccentric to the visual line act as prisms base in or out, and as the visual line in reading falls internal to that for distance, a compensatory prism must be added base in or out as the case may be. This is easily done with cemented bifocals; can be done, not so easily, in Ultex; and not at all in Kryptoks. See table of cylindro-prismatic displacements on page 56.

When we approach the problem of cataract bifocals, there enter many other than purely optical factors, although these also are intricate. Referring back to the chapter on the aphakic correction, all the factors entering into the refractional elements in the distance have been considered. Here enter those incident to the near.

The late Dr. Claiborne did the best possible with what means optical science offered at the time, but the results were of necessity bad. His plan involved the use of a Kryptok inset and in addition to the great distortional properties of his device, there was the distressing chromatic dispersion. Say he had a plus ten on a plus 2.00 cylinder at 180 for distance, with a plus 3.00 reading addition. The instructions to the grinder were as follows: Take a toric blank on a plus 6.00 base curve (plus 6.00 on a plus 8.00 axis 180) in which is incorporated a Kryptok plus 3.00 addition. Grind the posterior curve to a minus 6.00. Take a biconvex lens plus 6.00 on one side and plus 4.00 on the other, in size equal to the vertical diameter of the distance lens; grind this to a knife edge, and cement this into place. This lens was not unsightly, and at the time was the best way out of the difficulty. Now things have changed and we have the choice between putting in a Kryptok inset or grinding on an Ultex addition to our scientifically computed distance lens. Of course either of these must go outside on the spheric surface, and the Ultex only should be the choice. A plus three Kryptok addition can not be made free of spectral defects at the periphery. In making this lens certain minor optical exactitudes must be sacrificed. A Kryptok or an Ultex must be added on the spheric side. To add it on the toric side would result in eliminating the cylinder altogether with the Ultex, and increasing it with the Kryptok. Therefore, with a plus 10.00 on a plus two cylinder, the posterior curve is ground on a minus three base, and the anterior side made a plus fifteen. Upon this curve any addition may be ground in Ultex, making a bifocal which is practically, but not entirely, free from aberrational defects. It is hardly necessary to add that a lens of this kind is very expensive.

It is not enough that the optical essentials be met in prescribing bifocals for the ametropic presbyope. There enter also other factors peculiar to the individual wearer and the uses to which the lenses are to be put. For example, the clergyman, whose notes are at arm's length; his reading addition therefore must be weaker. Pertinent to this instance is the advice not to have these lenses made as deep menisci. The high outer curves catch all light reflections, make the wearer's eyes invisible through his glasses, and distract the attention of his auditors. He should have these lenses made flats and have another pair, properly ground and with stronger reading additions for use in his study.

Long-armed or short-armed persons must have proportional power to their needs. The short-armed needs a higher power than the other. Don't prescribe bifocals for a woman with a high bust. She can not use them without getting cramps in the back of her neck. Only by throwing back her head can she get the reading portion into position.

A nicety of judgment is required in the matter of the sportsman. With the golfer, the reading segment must be small, low-down on the distance lens, and its power about 0.62 diopter. For the marksman, if he be astigmic to any degree, bifocals are impossible. He should have his distance correction only, made up in amber glass, and his cylinder axis shifted fifteen degrees to the left to compensate for the tilted head in the aiming position. If he is left-eyed, his gun-stock will have an S-bend, so he can fire from the right shoulder; but he sights with the left eye, and now his cylinder axes must be shifted to the right.

For the ear, nose and throat surgeon, the near portion must be of short focus and be situate either at the top or the center of the lens. The old substitute for a bifocal, the grab-front, has been practically discontinued.

There is one kind of sportsman, the elderly type, to whom glasses of any kind, and especially bifocals, are an abomination. They are apt to scare away the game, and chickens are notoriously afraid of bright objects.

The housewife who does her own work can not wear bifocals with comfort. Much of what she has to do is in the middle distance and out of focus for the reading addition. For her two pairs are better, and for near work one must compromise. She does not read and sew at the same distance, so her glasses are made a little weaker than would be given were reading ability the only condition to be fulfilled.

A business man who is ametropic and presbyopic, most of all persons, needs bifocals. He needs his distance correction that he may see clearly the psychic effect upon his prospective customer of his business arguments, and he must be ready to close the transaction on the dotted line. A fumble for a pair of reading glasses may let slip the opportunity.

Many times the usefulness and comfort to the wearer of bifocals are nullified because of errors in fitting the frames. This matter will be fully elaborated in the chapter on the "Mechanics of Visual Appliances." Here only the size and position of the reading segment is to be given attention. Unless the inset is to be thrown low (golfers' glasses), the most useful size is one whose upper curve is on a long radius, and where the apex of the curve falls two millimetres from the geometric center of the distance lens. With a bridge of proper height the visual line should cut the distance lens one millimetre above its center. The directions to the optician are: "Let this lens be so placed before the patient's eye that the upper border of the inset is co-incident with the upper border of the lower lid." If the reading segment is too high, walking is difficult unless the head be bent downward; if too low, in reading the head must be tilted backward. This causes fatigue in the neck muscles. Many a time an accurate lenticular correction becomes unwearable because of inattention to this simple matter.

Many years ago a patient who needed a large angle range in the middle distance was fitted in the manner which follows: Distance needed plus one, intermediate 2.25, near 3.50. The instructions to the maker were: Take a plus 1.00 Kryptok blank with reading addition of plus 1.25. Grind a paster of plus 1.25 power to cover the lower two-thirds of this lens, and cement in place. This fulfilled the conditions as above stated.

Last but not least is the position of the reading segments. Theoretically their centers should be 2.5 millimetres internal to those for the distance correction, but it is not practicable, for if so set the segments will ride too high on the nasal sides of the lenses, They should be set inward 1.5 millimetres. In cemented bifocals the pasters can be decentered inward if necessary, but usually the small error is negligible. If laterally disposed prisms are necessary, they can be ground on. This is feasible in cemented or in Ultex, but not in Kryptoks.

CHAPTER XXII

MUSCULAR IMBALANCES AND THE CLINICAL USE OF PRISMS

In this chapter it is not intended to cover more than the elementary principles of this exceedingly complex subject. Even if the writer possessed a mastery of this phase of visual functioning (which it is doubtful if any man have) volumes instead of a single chapter would have to be written.

A necessary prerequisite to the proper understanding of ocular muscle imbalance is the comprehension of the normal muscular status. This implies not only a knowledge of the anatomy and function of each individual muscle but of the co-ordinated action of groups of muscles, for without such action in harmonious sequence comfortable binocular single vision is impossible.

In the process of evolution the orbital axes, from being at right angles to the sagittal plane of the body, have gradually approached nearer parallelism, but still lack about 23 degrees of having attained this. Within these diverging orbits are hung, upon arthrodial or universal joints, the spheric eyeballs whose antero-posterior axes are practically parallel to the sagittal plane, but whose muscles—excepting the obliques—take their point of origin internal to the three axes around which the eyeballs rotate and their insertions—excepting also the obliques—are anterior to the vertical and horizontal axes of rotation. The obliques, for our purpose, may be considered as having their points of origin internal and anterior and their insertions external and posterior to these latter axes. Their torsional action relative to the antero-posterior axis may be predicated from this description.

The proper understanding of muscle imbalances resolves itself into having a clearly visualized concept of these anatomic conditions; the diagnosis lies in its application and is largely a matter of mechanics. It is understood that the phorias are alone to be considered, that the tropias, pareses and paralyses are not under discussion and that the clinical picture is to be painted in broad strokes, with much of the minutiae omitted.

The action of individual muscles is simplest with the internal and external recti; the former is an adductor, the latter an abductor. In other words, their function is limited to an alteration of the ocular planes around the vertical axis.

In the primary position, that is, with the eyes directed forward, the superior rectus acts as a levator; to a lesser degree it serves as an adductor and intortor—that is, it turns the vertical meridian of the cornea nasalward. The inferior rectus, in the same position of the eye, has its chief function as a depressor, but its secondary action is that of an adductor and extorter; that is, it turns the vertical meridian of the cornea temporalward. The superior oblique is a depressor, but its action as an intortor is greater than that of the superior rectus and its abductor influence is its least function. The inferior oblique is primarily a levator; it is also an extorter and lastly an abductor. This covers monocular rotations, but when considering the eyes acting together in binocular single vision, the harmonious functioning to this end becomes much more complicated.

Of course, it goes without saying that finely co-ordinated muscular movements cannot take place without proper tonicity of the antagonists and that in the last analysis practically every binocular change of position of the visual axes calls for exactly correlated functioning of all twelve muscles, but only the prime factors will here have consideration.

Of associated movements, there are eight. These, with their dominant musculature are: Convergence, both internal recti; Divergence, both external recti; Both eyes to right, right external rectus, left internal rectus; Both eyes to left, right internal rectus, left external rectus. Down to right, right inferior rectus, left superior oblique; Up to right, right superior rectus, left inferior oblique; Up to left, left superior rectus, right inferior oblique.

Keeping in mind the oblique line of action of the superior and inferior recti it is clear that in extreme adduction their ratio of effectiveness is practically zero. In consequence the elevation of the eye when in this position must be accomplished by the other levator, namely, the inferior oblique. Now, in looking with both eyes to the right or left one of these must be in adduction and if then both eyes are to be turned upward only the one in abduction can call upon the superior rectus to lift it above the horizon; the other must use the inferior oblique for this purpose. The converse of this obtains when the eyes are to be depressed, for then the superior obliques must take up the burden.

Analyzing the muscular action of elevation and depression, it follows that beginning nasalward the inferior oblique carries all the load of superduction; this is reinforced by the superior rectus as the eye is being abducted. In the mid-position both act mutually and as the eye is still further abducted the load falls more and more on the superior rectus. In looking down, beginning nasalward, the superior oblique carries all the load of infraduction; this begins to be shared by the inferior rectus as the eyes are further abducted, until temporalward the latter is the most strongly acting.

From this it follows that if in adduction the upward rotation is impaired the underacting muscle is the inferior oblique, but if in abduction the same phenomenon is in evidence then the superior rectus muscle is the one at fault. Likewise, in adduction if this eye lags behind its fellow in looking *down* the trouble lies in the superior oblique, if in abduction the inferior rectus is the weaker muscle.

The practical application of all this is that there may be an imbalance of a levator or depressor which gives no signs of its presence when tests are made in the primary position, and may be detected only when these are made with the eyes in lateral rotation. Inasmuch as the phorometer can be used only when the eyes are looking straight forward (the primary position), it often fails to disclose the anomaly.

To appreciate the abnormal, we should know first the normal relationships. These are: In the distance, an orthophoria or a deviation from this either way not to exceed two degrees; in the near, an orthophoria or an exophoria not to exceed seven degrees, esophoria zero. An esophoria in the near is always pathological. The convergence near point, that is to say the nearest approach to the eye at which single vision can be maintained, is normally from 4.50 to 9.00 centimetres.

Dealing with the phorias alone there can be only two causal factors to be differentiated in the diagnosis of the muscular anomalies, namely over or under action or a combination of the two. Esophoria and exophoria are commonly associate disturbance of the lateral recti, but in the hyper- or hypo-phorias it is a single levator or depressor which is at fault. There can be no such thing as an insufficiency of supra or infraduction, as this would involve an inadequacy of function in the co-ordinated action of recti and obliques. It is true there may be an associate failure of infraduction in which the obliques participate, but this is a paresis of nuclear origin and its discussion is not germane to the subject under consideration.

The phorias have three basic and underlying causal factors, structural, innervational and insertional, any one or more of which may be active. An esophoria may be a convergence excess or a divergence insufficiency. Likewise an exophoria may be a divergence excess or a convergence insufficiency and in mixed forms there may be a convergence excess with an associate insufficiency of divergence or a divergence excess with an associate convergence insufficiency. A hyperphoria may be an over or underaction of a levator or depressor, and the fault may be either in the obliques or in the superior or inferior rectus muscle. One must keep clearly in mind the physiology of the ocular rotations if one is to unravel this apparent complexity, and the necessity for this understanding must serve as my excuse for the lengthy prologue which precedes the consideration of the diagnosis of the oculomotor imbalances.

That no clues of importance shall be missed a certain routine must be followed. First, should be determined the deviations in the distance—the primary position—by means of the screen and parallax test, the phorometer or the Maddox rod. The test object is a small light at twenty feet. The phorometer tests are of use only in determining the type and degree of the imbalance—it does not analyze the nature of this; likewise, the Maddox rod and light are so subject to confusing factors that no absolute reliance can be placed on their findings. A much simpler test than either of these is to place before one eye a dark smoke glass. This diminishes the impulse to binocular fusion, and should diplopia result, the position of the false image tells at once the type of the imbalance; if on the same side as the glass, it is an esophoria; on the opposite an exophoria; if above, a hypophoria; if below, a hyperphoria. The amount may be determined by the strength of a superposed prism which vertically brings the images on the same horizontal line or laterally causes the images to fuse. The screen and parallax test gives more truly evidences of imbalance and is less open to error. Screen each eye alternately by a card, the patient fixing on the light in the distance, and note the behavior of the eye behind the card, and now it returns to fixation as the other eye is occluded. If a heterophoria exists, the light will appear to the patient as though it moved. The excursion—up, down, right or left—will determine in what class the imbalance belongs. In the occlusion test place prisms of increasing power with the bases toward the weaker muscle until the excursion of the eye is opposite its original line of movement. The prism strength which induces this, less two degrees, is the measure of the deviation. Incidentally, it may be noted that divergence anomalies are always in the distance.

Of greater importance are tests made in the near and especially in the oblique meridia. The test object may be a small electric light or a white headed pin on a short wooden rod. For associated movements, let the patient's eyes follow this object as it is moved into the six cardinal positions. In other words, the test object is made to describe a circle about 20 inches from the patient's face. As the eyes follow the object, alternately cover and uncover each eye, and note the movement of recovery of fixation in the several positions. By this same test, not only are associated movements determined but also anomalies in individual muscles.

It is to be remembered that with diplopia the false image is always in the line of action of the affected muscle and that the images get further apart as the test object is moved more and more into such field. For instance, in testing the inferior oblique—say of the right eye in extreme adduction—in this position this muscle is the sole levator, therefore, as the patient is told to look up at the test object, if there be an insufficiency of this muscle vertical diplopia results, either crossed or homonymous, but which grows less as the eye passes from adduction to abduction.

If there be a hyperphoria, in some part of the upper or lower field, there will be either diplopia or, if the imbalance be of low degree, a return to fixation which may be detected by the cover test, and the movement by which this is done will tell you which of the levators or depressors is at fault: In the esophorias, there may be convergence excess or divergence insufficiency. In the former, the error increases as the object is brought nearer the eye—*i.e.,* the esophoria is greater for near than it is for distance. In divergence insufficiency, the reverse obtains, as the esophoria is greater for distance than it is for near. An exophoria which increases in the near and is less for distance is a convergence insufficiency; if greater in the distance and less for near, it is a divergence excess.

There is one type in which both divergence and convergence insufficiency may coexist; in this case there is exophoria in the distance and esophoria in the near. Cases in which an esophoria occasionally becomes an esotropia—periodic squint—are usually due to spasm of convergence. Seen behind the cover card the eye turns in and when shifted to the other side the eye moves out to fix. This type is the one which may be benefited by correction of the usually associated hyperopia; the esophoria of a divergence insufficiency will not be.

As was said in the opening sentences, the subject was to be covered only as it dealt with the phorias and with typical instances. I doubt if anyone has completely mastered all the intricacies which follow secondary spasm or the disfunctioning of a weakened muscle, but if in what has been said here has been given a sufficient résumé to make this fascinating subject perhaps not clear, but more nearly so to you, and will help you to differentiate the muscle imbalances which are so commonly encountered, my object will have been attained.

Let me urge a test in all the cardinal positions in every case and you will be astonished to find how often this will give you the clue to an asthenopia that has resisted all forms of lenticular correction.

Maddox has described a simple expedient which will often give a clue to muscle-imbalance in the primary position. Using a concave mirror of long focus the patient is asked to fix on this, say at a distance of four feet. The light, from a source behind the subject, is reflected into the patient's eyes. Now are seen, upon the corneae, bright reflexes as small luminous points. If these occupy the centers of the corneae orthophoria may be predicated, if one or both are internal an exophoria may be predicated, if one or both are external to the corneal centers, esophoria may be suspected. A hyperphoria shows as a misplaced downward reflex; a hypophoria, one upward.

Incidental but not wholly pertinent to the subject are the pareses of conjugate movements occasionally encountered. It has been held that the return to parallelism after convergence was purely a negative response. This is an error, for while the position of the nuclear center for divergence has not been determined, it most surely exists. Cases in which sudden homonymous diplopia has appeared, often associated with marked somatic disturbances, headache, nausea or vomiting are not so very rare. The symptoms are characteristic. At and within a fixed distance, varying with the degree of the paresis, there is binocular single vision. Beyond this, with wider separation of the images, as the test light is carried farther away, double vision occurs. If one eye be covered with a red glass, the patient sees the red light on the same side of the glass, but as the test light is brought nearer, the two images fuse. It is probable that the lesion causing these phenomena is in the floor of the fourth ventricle. Suggestive is the fact that these cases occur most frequently during an epidemic of encephalitis lethargica, and may be due to the same microbic infection, or even be its sole manifestation. Dependent upon the amount of nuclear destruction or simply its disturbance, do these cases recover or the paresis of divergence remains permanent.

So far as treatment in the primary stage is concerned there is, for the employment of any internal medication, no rational basis. How many recover I do not know. In all, I have seen six cases. Three got well with no treatment except for sedatives; in two the patients passed from under my care; and the sixth is now under observation. Should the condition remain permanent, there remains only recourse to advancement of the external recti. Optical treatment is ineffective. Pareses of dextro- or levulo-rotation are cortical; of sursumduction are basilar (thalamic) in origin.

With this little digression into adjacent territory, we return to the question of what shall be done optically to correct a muscular imbalance, how far to go and how wise is the application of this correction. Shall we correct all cases of hyperphoria with prisms base up or down, and how much of this error shall be compensated for? Speaking generally, such cases as are due to pareses of sursumduction should be corrected to almost if not the full amount. A patient with paresis of a levator will not take kindly to prismatic additions. There enters also the question as to how much lateral imbalances are due to refractive errors (esophoria in the hyperope, exophoria in the myope), and for how much is torsional imbalance, in an oblique astigmia, responsible for the pseudo hyperphorias. The use of laterally disposed prisms seems to me illogical. The tonicity of a crippled muscle is certainly not improved by placing a prism with its base toward it. Lateral imbalances in the near may need correction and especially is this true for the presbyope with a wide pupillary distance and an insufficiency of convergence. If this is marked and accommodative help urgent, prisms base in must be added to his reading correction or he will get crossed diplopia at his punctum legendi. If in addition to his convergence loss he have also a vertical error that needs correction, we may correct both lateral and vertical imbalance by a single prism obliquely placed. To find power and position of this prism, divide 90 by the sum of the two prisms and multiply result by the power of the weaker. This will give the base apex line. For power, take the sum of the squares of the two powers and extract the square root; this will give strength of the prism. For example, exophoria, seven degrees; hyperphoria, two degrees; 90 divided by (seven plus 2) equals ten, multiplied by two, equals twenty. Now we have the departure from the horizontal in degrees, and where the base apex line should be placed. Squaring seven and two, and extracting the square root, gives 7.25. If the hyperphoria is of the right eye, this prism should have base apex line at 160, base in; if the left eye, base in at 20. In the prescription this is divided between the two eyes. For a right hyperphoria we need a one degree prism base down over right, one degree prism base up over left. The prescription therefore will read right eye 3.62 prism base line in at 160 left eye the same. In exophoric cases, especially in the young, prisms should not be prescribed until all other methods have been exhausted.

First, a most accurate correction of the refraction, second prism exercises for the weak interni should be tried, if it be a convergence insufficiency; divergence excess does not respond to these save in minor degree. An exophoria may or may not give trouble, depending upon how great is the power of convergence. This type of divergence excess with a near convergence point at four contimetres may even go undiscovered. As example, an exophoria of 11 degrees with a left hyperphoria of 2 degrees, in a medical man who uses his eyes at close work all day long, gives him no trouble whatever, and why? His hyperphoria is due to a paresis of a levator (right superior rectus); his point of near convergence is at three centimetres; below the horizontal he does not use the levator, and his super-normal convergence takes care of the other imbalance. Insistence upon the refractional correction is made because certain types of muscular imbalance are associated with refractional errors and will disappear under constant wearing of the proper glasses.

The normal relationships of convergence and accommodation are disturbed in both hyperopia and myopia. The hyperope has a leaning toward excess convergence, the myope toward divergence. Often improperly fitted glasses induce false heterophorias and especially is this true in oblique astigmias. An astigmia at a divergent axis (R. 105 or L. 75) calls into play the superior oblique that images may fall on corresponding retinal points. Its depressor effect being so much greater than its intorting power, an over-action gives an apparent hyperphoria in the other eye. An exact correction of the astigmia eliminates this heterophoric element. Even an exact correction for distance vision may give rise to a hyperphoria, where strong oblique cylinders need to be employed, if the lenses are badly mounted and not properly centered. Due consideration must be given this point; also for whole lenses at the punctum agendi.

A compromise must be made between centers for distance and near. This applies of course to glasses for constant use. When for reading only, both lenses should be decentered in 2.5 millimetres.

Cases of exophoria due to convergence insufficiency, and these are in the majority, rarely are amenable to optical treatment. Those due to divergence excess, without complications and apparently stationary, may accept gratefully prismatic assistance. In the young, adduction exercises should be faithfully carried out. The older patients need surgical intervention.

In esotropia (convergent concomitant squint) give the full cycloplegic correction, less 0.25 diopter. If this corrects the esotropia for distance, but if the eye still turns in when reading, give a plus 2.50 addition in Kryptoks. These are specified because a child is subject to ridicule if conspicuous lenses are worn and is inclined to discard the glasses in public.

Most of the hyperphorias are insufficiencies or actual pareses of individual muscles. Hyperphorias due to levator insufficiency rarely will accept prisms base down; to those of the opposite type (depressor insufficiency) correction is grateful.

The esophorias of the comitant type (associate hyperopia) are often cured by full lenticular correction, as may even be esotropias (comitant squint), but it is impossible to forecast results. Even with low powers (plus one or two) results may be satisfactory, but the greater the error the better the chances.

In associate refractional errors and muscle imbalances, correct part or all according to the type. Hyperopia with exophoria, undercorrect; myopia plus exophoria fully correct; with an associate esophoria undercorrect, and a hyperopia with an esophoria should be fully corrected.

CHAPTER XXIII

THE MECHANICS OF VISUAL APPLIANCES

It is a safe bet that half of the discomforts which ensue upon wearing glasses are due to faulty mountings, the other half to faulty refraction. In a Florentine church there stands a tombstone dated 1317, upon which is inscribed: "Here lies Salvino D'Armato degli Armati of Florence, inventor of spectacles. God pardon him for his sins." If he had been the inventor of some of the spectacles we see in 1926, nothing short of plenary absolution would have got him through the pearly gates. Look with a critical eye at the wearers of glasses you meet in public places. Not one in fifty is properly fitted. The lenses are too high, too low, too wide, too large, too far from the eyes or else too near. There is no earthly reason why this should be so, and as for eye glasses, not one in a hundred is in proper adjustment. The American type of nose does not lend itself to this form of visual appliance. Only those who have a nose with abundant tissue at the base, thinning down to a slender tip, should be permitted the use of eye glasses, and not even then if their correction includes a strong cylinder. The guards on an eye glass are constantly altering the contour of contact, and will not stay in adjustment even if the initial position were correctly placed.

There are two unalterable factors which govern the size of lenses, the distance between pupillary centers and the thickness of the nose at the root. This measured where the curl of the bridge shall fall, and subtracting this in millimeters from the pupillary distance (inter-pupillary distance) also in millimetres, the difference will give the transverse diameter of the lens which is suitable and wearable for this particular case.

It may be asked why all this, and what follows, needs to be written at all. Daniel Webster once said: "If there be anything beyond the foreknowledge of God, it is the verdict of a petit jury." This might aptly apply when your prescription gets into the hands of the dispensing optician. The refractionist of a large city thinks his work is done when his order goes into the patient's hands; the refractionist in small places must attend to the mechanics of frames and fittings himself. To both of these am I writing, for my experiences cover both fields. If the city dweller knew just what should be done, and the other knew what can be done, the patient's interest and comfort would be better conserved.

The two factors that have been given, width and pupillary distance, are governed by a third, the positioning of the lens, measured from its back surface to the apex of the corneal dome. This trinity is like the law of the Medes and Persians, it altereth not. The anterior focal point, 14 millimetres, must be co-incident with the posterior curve of the lens, even if the lashes have to be trimmed to make them correspond.

Speaking of spectacles, the curl of the bridge should come so far down on the side of the nose as to give a firm support. Now if the patient have protuberant eyes, and the optician has not in stock a bridge with long shanks, he will bend, from an unsuitable mount, some of the curl into the shank with, in consequence, an insecure resting place upon the patient's face. If the patient have a narrow pupillary distance and a thick nose, and the frame in stock have too large an eye, he will throw the shanks under to bring the lenses closer together. This is not a bad fault, provided it is not carried too far; but if in so doing the *rims* are made to touch the patient's nose, it is fatal to the wearer's comfort. Without ventilation around the rims, perspiration will cause the glasses to be fogged by precipitation. Again, if the pupillary distance is very wide and the frame carries too small lenses, the shanks will have to be bent out to carry them farther apart. This never should be done. It is very unsightly and the patient is apt to look around the lens on the nasal side.

Lenses should never be decentered for distance. By this is meant, throwing out or in the optical centers. If the lenses are the proper size for the pupillary distance, it is not necessary. Of course if a prismatic effect is desired, this may be done; otherwise the mid-distance of lenses and pupils should be co-incident.

Lenses so large that the visual line falls internal to the geometrical center give the patient the appearance of a convergent squint. Too small are equally bad. The only patient who should have too large lenses is the one who is exotropic. These minimize the disfigurement.

Perhaps the most common fault is a wrongly bent crest angle. Stock bridges are angled at 45 degrees from the plane of the lenses. Noses are more often at 40 or 50 degrees to the facial angle than they are at 45. The routine angulation in the first instance makes the bridge cut into the nose above; in the second instance below; in either event the patient suffers discomfort. The cylinder bridge is an attempt to meet this discrepancy. In appearance it is not so neat, and to order this type is a confession of incompetency.

Lenses for near work often require decentering, and especially is this true for high powers. The facial contours may prohibit a geometrical decentration, as by so doing the rims may be thrown against cheek or nose. Optical decentration then becomes imperative. At times it may be necessary to combine both. In this event the octagonal lens will give ample leeway.

Incidentally there is a type of face which can not be properly suited by any other form of lens. With a thick nose, high cheek bones and a narrow pupillary distance, and especially if the face is a long oval, we get proper dimensions only by taking an oval lens and cutting through an arc on all sides of the ellipse. This permits a closer approximation to the nose, gives a larger transverse diameter and clearance to both nose and cheek. If rimless, the edges should be outlined in rim paint. This prevents reflections better than does the dull finish. For the super-sensitive to this form of annoyance the edges may be cut on a sharp bevel, but they are not good to look upon, the lenses appearing to have a ring of light bounding their peripheries.

The depth of bridge must be such that the lenses will come at 14 millimetres from the cornea, and of such height as will allow the visual lines to fall about two millimeters above the center of lenses. There is a natural position of repose where the bridge must lie upon the face, and that is where the vertical line of the brow and the angular one of the nose coincide. The temples should only be tight enough to hold the bridge in this position. If the height of bridge is too great, no amount of tension will keep the lenses from falling too low.

The temples or bows should be of ample length, should come lightly in contact with the sides of the face when in position, and so angled that the lenses tip out slightly at the top, making their planes co-incident with the bases of the orbital cones. This is purely for appearance's sake, and if something other than a point-focal lens be ordered, then this position helps to give a clearer image below the horizon, where mostly glasses are subject to use. Where there is a marked difference between the height of the two eyes, the refraction must be worked out with the external canthi taken as a base line and the trial frame tilted on the face to correspond with these two points.

The cylinder axes are then ordered in the position so found, and when the glasses are made up, they are angled across the face by bending down one temple. Of course one might use the trial frame at right angles to the long diameter of the body, and then lower one of the spectacle lenses by bending at the shank. In either event, the refractional, but not the cosmetic, requirements are met. One glass lower than the other is very unsightly; spectacles slanted across the face are not noticeable.

In what manner lenses should be mounted depends upon whether they be plus or minus. Plus lenses are thinner at the edges and so are liable to breakage if mounted rimless. With rims of medium thickness, or of metal construction, even high power lenses can be greatly cut down in weight by grinding the edges very thin. A minus lens looks better also if made a deep meniscus and the bevel cut from its posterior surface. A heavier rim should be used so that it may partially conceal the peripheral thickness. Sphero-prisms (base in or out) demand the same treatment. Lenses of high minus power may be mounted rimless if they are made lenticular. This type has an elliptical refractional area from which the glass slopes away to the edges. It has the disadvantage of greater cost and a smaller field, but is much lighter in weight and is less conspicuous.

The ideal mounting for all types of lenses is made of white gold, and the rims come flush and continuous with the lens margin. The cross-section of the eye wire is ribbon-shaped, and one can hardly see where lens ends and rims begin. As I have said elsewhere, round lenses should never be prescribed and especially is this true if a cylindric element is embodied in the lens and if they are mounted in rims. The lenses may loosen in their settings, and thus cylinder axes may become displaced.

There are many kinds of eye-glass mountings, and this of itself argues against any perfect one. Two useful types are the finger-piece and the one-piece with guards and spring integral. The latter is the better of the two, as it admits of nicer adjustment. The type where guards, spring and posts are separate, but assembled, is best of all, even though it is not quite so neat in appearance. With this every adjustment necessary to exact fulfillment of conditions may be obtained, and guards of many models suitable for differing types of noses may be selected. The lenses may be placed up or down, in or out; they may be brought, either one or both, closer or more removed from the mid-nasal line; and length of spring may be made proportional to width of nose.

There are certain conditions which bar absolutely the use of eye glasses: The Mongolian or Ethiopian type of nose, high astigmia, anisometropia with unequal weight of the two lenses, cataract cases, patients with a wide pupillary distance and a narrow nasal width, and those whose nasal slant is abrupt and thinly covered with flesh. With the latter the guards pinch up this covering into ridges which appear as vertical folds between the eye-brows and spoil the profile. From every standpoint, utilitarian, cosmetic or optical, spectacles should be chosen and in almost every instance should be insisted upon.

For his own protection and the patient's, it is imperative that the refractionist subject the finished product to a rigid inspection. If you are familiar with the technique of the grinding room, you know how easy it is for errors to occur. Theoretically a cylinder axis should fall exactly where it has been ordered, but in practice this result is exceedingly difficult to attain and especially so in low powers. Even when scrupulous care has been taken in spotting the lens, the edging may shift the axis and still leave the lens-oval perfect. In the higher powers, 1.00 diopter or over, there is no excuse for a misplaced marking; nor should even one degree leeway of error be permitted to pass unchallenged. With fractional powers 0.50 diopter or less, one or two degrees off axis may be permissible. Patients should be told that no responsibility can be taken, nor comfort assured, until they bring the glasses back for your approval.

The first step is for mechanical excellence. Are the glasses in proper position on the patient's face, and are the lenses accurately spaced for height, the pupillary distance and the right distance from the cornea? If fault can be found with any of these dimensions, the glasses should be sent back to be placed in another frame which corrects any fault so found.

If the frame fits, the next step is to see if the lenses are properly aligned. Placing the glasses face down on a straight edge, note if the end pieces and shanks are on the same straight line. Don't take this line from the curl of the bridge. Very often a little twist to the shank must be given to make the long axes of the lenses co-incident. Assured of their conformity, the glasses are put upon the patient's face and inspected for position. Here we take as criterion a line bisecting the two pupils, and not the relation of lenses to eye-brows. These are often not of even elevation. It needs something more than faith to accept anthropomorphism, for the creature is certainly lopsided. Rarely is it found that the ears are on the same level, and to bring the glasses up to proper transverse lineation, one temple must be bent downward. This is done on the side on which the lens is lower. To do this properly there should be an angulation of the end piece, and not a bend made in the temple.

Lenses can not be tested for accuracy by neutralization from the trial case. Plano-spherics (plus or minus) do not neutralize point focal lenses, and as for cylinder axes, it is a pure guess as to their positions. Every refractionist should own a lensometer, not as an ornamental piece of office furniture, but for daily use. When I first began my daily dozen with mine, the optician received, as a testimonial to its efficiency, a return of about one-quarter of his work. When he knew it was working regularly, this prophylactic applied to his inspection department resulted in a great drop in the infant mortality.

The first thing is inspection for physical faults, bubbles in the glass, over or under polishing, chipped edges, or (in rimless mountings) an improperly drilled screw hole. The ordinary lensometer (Lloyd's axometer) will reveal power of sphere and cylinder and its axial position, but will not show faults in centering. Errors in this, sufficient to condemn the lens, may however be detected by the eye. Hold the lens an inch or two above the corner of a square cut card. View first the lateral line of this through the lens. Moving the lens laterally until the line seen through it and that part above and below it are continuous (if an oblique cylinder is a component, the lens will have to be rotated to accomplish this). Now, moving the lens down, apply the same test at the lower margin of the card. If the lens is properly centered, the corner of the card will fall in the center of the lens. If you do all these things, you will have protected the patient's interest and your own, but to your optician you are likely to become persona non grata.

Perfect optical work is not enough. The patient must be instructed in the use and care of his glasses: How they should be put on, how taken off, how cleaned and how disposed when not in use. There are only two ways of doing these things, the right way and the wrong. The right way only will here be described. The patient will find all the wrong ones for himself.

In the first place, spectacles once opened should never thereafter be closed. Frequent opening loosens the temples at the joints and impairs adjustments. When removed for the night they should be placed resting on the edges of the rims and the receding curl of the temples. Never should they be closed and put in the case, nor permitted to rest lenses down. Optical glass is soft, scratches easily, and marred lenses lose in effectiveness.

In cleaning glasses they should be held by the end piece, not by the bridge. Even firm shanks will eventually yield and throw the lenses out of adjustment. Soap and water should be frequently used. Soiled glasses will of themselves induce eye-strain.

It takes both hands to put on or take off a pair of glasses. To put them on, they should be held by the end pieces between thumb and finger, the concavity of the bows away from and facing the user. When the hands are brought up, the curl of the temple will fall naturally into position. The curl is first slipped over one ear, and then over the other. To facilitate this maneuver, the face is alternately shifted to the opposite side.

In taking them off, the left end piece is grasped between thumb and finger, the right thumb and finger is slipped along the temple up to the ear-curl, and this is lifted up to clear the upper lobe. The left temple is now free to be lifted off. To put both bows in position simultaneously cannot be done without wiping the lashes off on the lenses. To drag them off by main strength spoils the set of the curl behind the ears.

A certain patent medicine was guaranteed to cure if taken according to directions, which were: Internally, externally and eternally. These, except the first, applies to glasses also. They should be worn during all the waking hours, they should be kept scrupulously clean, and absolutely exact in adjustment.

CHAPTER XXIV

THE COSMETIC VALUE OF GLASSES

Beauty, it is said, lies in the eyes of the beholder. The flapper has a pulchritude peculiar to herself, but this is largely youth and color—not always natural. She appeals to the eyes of youth because like calls unto like. She never can be called beautiful; she is only pretty and usually insignificant. The beautiful woman is a rarer type; she must have featural perfection but not necessarily brains. The handsome woman must possess both. These outward symbols appeal to the eye alone, but we, whose study is the windows of the soul, must see the expression of the spirit which shines through them if we are to attain perfection in our art and the highest pitch of usefulness to our patients. It is character that counts, and this, like baptism, has an outward and visible sign of an inward and spiritual grace.

To accentuate and not to mar the facial expression of personality is part of our science, and he who fails to recognize this fact falls short of perfection and becomes the bungler rather than the artist. Abraham Lincoln said that God must have loved the common people because he made so many of them; by the same criterion, he must have loved the homely ones also. Few there be who have featural perfection, and it is fortunate for us that this is so. It is extremely difficult to select mountings which will not detract from the appearance of the really handsome, but there is no type of face of uncomely feature which can not be made more attractive, nor is there any deviation from the accepted standard of good looks which can not be minimized by a judicious choice of frames or mountings.

The ancient Greeks formulated a rule of facial symmetry in which the mensural values were in thirds, one part to the forehead, another to the nose and the last to the mouth and chin. These three should be equal; the nose should be straight, the eyes wide apart, the brow broad and the face a regular oval. What the so-called beauty specialist does in the way of surgery to correct featural imperfections is here outside the mark, but incidentally, it may be said that not being an artist, what he does to alter the physical lines of the nose, mouth and cheeks, throws the whole face out of balance and converts what may have been a face of character into a featural monstrosity in which distinguishing characteristics have been sacrificed to regularity.

What we aim to do is to take advantage of the laws of optical illusions and so to modify the facial discrepancies of proportion as to make these no longer evident. Perhaps the most important feature, certainly the most prominent, is the nose. In types there are the long, the short, the aquiline and the pug. To camouflage these irregularities is easy, if we remember that length is apparently shortened or otherwise by a distinctive point of departure; that lines drawn vertically increase and drawn horizontally decrease the apparent length of an object. Therefore, if the nose is proportionately too long, we order in spectacles a low bridge; or in eyeglasses, a finger-piece mounting. With either of these in position on the face the eye of the observer estimates the length of the nose from the bridge down, and not from where it starts between the eyebrows.

If the nose is too short we place the point of departure higher; if spectacles are required, we use those with nose pads to bear the weight and with a high square bridge; if eyeglasses are suitable, an anchor guard, with a high square spring, should be ordered. A hoop spring is never becoming on any type of face, and should not be used. The nez-retroussé—"pug" in the vernacular—should have the square spring to make it appear longer and, if the flesh over the root is loosely attached, this may be brought forward by the guards on an eyeglass and, by so doing, we minimize the concave curve of the nose. If the nose be aquiline, an ordinary spectacle bridge accentuates this feature; therefore, nose pads in spectacles and a Grecian spring in both these and in eyeglasses should be chosen, the height of the bridge being governed by the length of the nose and, as such a feature is usually long, the bridge should be low.

Patients with large and broad faces do not look well in spectacles; the temples accentuate the breadth of the face and if age begins to leave its hall-mark on the countenance, the line of the bows simulates a crow's-foot at the outer angle of the eye. Eyeglasses are much more becoming after we have passed our première jeunesse and the objection is sound of those who will not wear spectacles because they say they make them look older.

The selection of the size and shape of the lens is also a matter of nice judgment. There is one dimension, however, in which is given us very little latitude, and that is the long diameter: this is governed by two factors—the interpupillary distance and the width of the nose at base—and the difference between these gives us the length of the lens. In spectacles, there is a little leeway but only a very little, as shanks should not be thrown under, or but very slightly so if becomingness is to be attained.

With a thick nose and a narrow pupillary distance, rimless spectacles are the better choice; but if the patient must have eyeglasses, then an anchor guard, with zero posts, or a narrow pupillary distance fingerpiece mounting, also with rimless lenses, should be ordered. A wide pupillary distance and a nose narrow at the base cannot be becomingly fitted with eyeglasses; either the lenses must be too large or the posts too long.

After having fixed upon the length of the lens, what shall be its vertical diameter? In the first place the two should never be the same; that is to say, a round lens should never be ordered. This is not only because of the risk of the cylinder-axis shifting in the frame, but because a round lens, by an optical illusion, does not look round when put upon the wearer. It has the appearance of a vertical oval, and to every type of face is unbecoming. If the patient insist on round lenses, add two millimetres to the horizontal measurement and subtract two millimetres from the vertical diameter. Now without being so, the lenses will look round upon the face. There is another reason why, from a cosmetic standpoint, round lenses are unbecoming, which will be mentioned later.

Considering that horizontal lines apparently broaden and vertical lines narrow an object through which they are drawn, the long, thin face should have regular oval, the full face short oval and the moon-faced type lenses more nearly round. Never, in any circumstances, have the interpupillary distance of the glasses greater than that of the patient, unless there be an exotropia. Glasses too wide make the eyes look too close together and give the appearance of a convergent squint.

The eyebrows give character to the face and should never be covered nor encroached upon by the frames. If this be done, the lines of the face are broken and this mark of individuality obliterated. It is not always an easy matter to observe this restriction and still have the glasses come high enough for comfortable seeing. For overhanging and bushy eyebrows, Galezowski's model—the leaf-shaped pattern—should be used, as this will come up close under the brow. If the eyebrows are thick, these lenses should be rimless; if thin, rims may be worn.

If the eyes are deep set, use flat lenses; if prominent, torics; but do not put the latter upon one who speaks in public, as they catch the reflection of every light and this distracts the attention of his auditors.

Do not place the lenses too high, for while it is essential, in the primary position, that the pupils coincide with the mid-vertical meridia, the horizontal meridia should be two millimetres below the pupillary centers. In children and in very tall individuals, the cosmetic values must, in a measure, be disregarded. For children, who more constantly look up, the lenses must be higher; for the very tall, who are compelled to look down, their position must be lower than would usually be the case.

Of equal importance to position and form is the matter of color, but here sometimes occurs a clash between the latter two, and it requires a nice judgment to reconcile their differances. Dark-colored rims serve to minimize large features and light colors give to the face an appearance of greater size. Brunettes should wear dark rims and blondes light-colored ones, but if a blonde have large features, the latter first demands consideration and the rims should then be dark-wine color; also by reflection such rims heighten the coloration of a pale blonde; but in this age, when the paint box is so much in evidence, little attention need be paid to this point. Gold rims also impart a coloration, but they are largely out of fashion just now. The matter of coloration in a brunette with small features is a negligible factor—for them, rimless lenses are indicated.

The library spectacles and the heavy shell bows should be confined to the library—not one face in a million looks well in them. Beware of heavy rims on a face with high cheekbones; the shadows thrown by them only bring these out the more in prominence. The Oxford eyeglasses are becoming only to such faces as are large and whose features bear the stamp of distinction; upon small or commonplace faces, they are an optical atrocity. It is pleasing to note that rimless glasses are coming again into fashion; the pendulum is swinging from extreme of size and conspicuousness back to the more esthetic and beautiful type. The American shape of face runs rather to length than to breadth; the light rims and rimless lenses make the face look broader, and the regular oval shape still further increases the illusion.

It may be urged that with all this the refractionist has nothing to do and that his business is the correction of optical and not featural defects. It is not true. We are dealing with human nature, as well as with human vision. Vanity is only an exaggerated self-respect. We would be less than human did we not all possess it, and you may be assured that it is not confined to the female of the species. We owe it to our self-respect that we shall all look as well as possible, and the refractionist who considers seriously the appearance of his patient rises above the mere routinist and becomes the artist and one worthy of the dignity of his calling.

EPILOGUE

The pure science of optics is our common heritage; applied, it becomes an art and peculiar to the individual. One may not evolve out of his inner consciousness all the facts given in this little book, and to cite chapter and verse, of alien source, is not only impossible but supererogatory.

I am aware how incomplete must be any treatise dealing with an art that no man can master, but I have benefited in the writing, and I trust others may be in the reading. With appreciation and gratitude to those who have been—unconsciously—his collaborators, the author appends, in lieu of bibliography, three apropos quatrains anent his illustrious namesake:

"When 'Omer smote his bloomin' lyre,
He'd 'eard men sing by land and sea;
And what 'e thought 'e might require
'E went and took, the same as me.

"The shepherd girls and fisher men,
The soldiers and the sailors too,
They 'eard old songs turn up again,
But kept it quiet, same as you.

"They knew 'e stole, 'e knew they knowed;
They never told nor made a fuss,
But winked at 'Omer down the road,
And 'e winked back, the same as us."

THE END

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